ENGINEERING FOR ESTATES

THE PRINCIPLES

OF

CIVIL ENGINEERING

AS APPLIED TO

AGRICULTURE AND ESTATE MANAGEMENT

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LONDON

KEGAN PAUL, TRENCH, & CO., 1 PATERNOSTER SQUARE

1885

PREFACE.

THE contents of this book are intended to afford the owner or his land agent, and others interested in such matters, such information as modern agricultural operations demand. It is to be noted that some special machines are described, such as steam ploughing engines, steam fire engines, &c., as the manufacture of some particular firm; when this is the case, and it could not be avoided, it is to be understood that such matters form the subject of patents, and that their selection has been made from results obtained at public trials; my object being to avoid distinctions in firms and their manufactures, except where public trials or private experience dictated that such want of special classification would negative the result the book seeks to attain, which is to improve and render more in accord with modern scientific knowledge and the practice of engineering, the general operations in the economical management of landed property. The

experience the writer has gained, both at home and in Australia, South Africa, and elsewhere, has convinced him that an immense field is open to the English agricultural implement maker, if only he can be persuaded that 'the best of what they use at home' is what the Colonial agriculturist requires, and the cause of great disappointment to farmers emigrating may often be found in the fact that they are not acquainted with surveying and the use of machinery. But so long as the practice of neglecting to move with the times prevails at home, the wants of the farmer, and the means of satisfying them, are at a standstill. With State education we are entitled to look for higher intelligence, and the man of the future will be able to use a dumpy level for drainage where his predecessor failed to discover the necessity of putting in a drain at all. The present call on the pockets of owners of property is greatly the result of the bad work of former years. The excuse was want of education; that excuse is now worn out, and with modern education and some engineering knowledge, the failures of the past should not be repeated. The writer's object, therefore, has been to endeavour to bring that practice of civil engineering that should apply to the management of land within the grasp of those who now have daily need of it, and also to provide a book of reference for agents, farmers, and bailiffs. One of the most remark-

able features of the century in education is the slow but complete training up of men to work our great railway system; in the process, an extraordinary amount of genius and perseverance has been unearthed; the same process has now to be carried out by means of education of a technical kind amongst the classes that work our land, and is there any reason to doubt that in doing so, the same qualities may be unearthed?

Bad work begets bad work, and the effect may be seen in the want of care of agricultural implements, and in the disregard to economy of material and labour. The farmer is loth to believe that the railway contractor will drain a field whilst he is consulting the weather, and 'getting ready to sough it.'

There is no difference between agricultural or any other sort of drainage or general earthwork. It is a simple contractor's question of means and men and the least time with the least material. The farmer has been accustomed to look on it in the light of day work. That is where his capital goes. The landlord uses the wrong or obsolete materials; that is the cause of the enormous proportion of estate expenditure to income. I am convinced that a great saving can be effected by paying more attention to detail in construction, and that the want of modern sanitary knowledge greatly adds to the number of men who are an unnecessary burden to the parish through premature decay.

These things are remediable, but not so long as the modern researches into the laws of health are neglected. But it is from the owner of land that this modern stimulus must come. Gathering enormous crowds together in London to talk upon every subject but the one they are supposed to have come to study, will not convince the farmer of the evils of impure water and undrained land. It is in insisting on work being done in a modern way that will save his pocket, and that is the most direct appeal to his reason.

The author, therefore, hopes that, in the publication of this book, the Principles of Civil Engineering have been brought within the wants and acquirements of those who derive their income from land.

Experiments on ensilage being still going on, only what has been accomplished in that direction has been touched upon.

ALAN BAGOT.

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ENGINEERING FOR ESTATES.

PART I.

ON SURVEYING, LEVELLING, DRAINAGE, AND WATER SUPPLY.

CHAPTER I.

INTRODUCTORY.

THE increasing application of machinery, and the necessity for economy in our agricultural operations brought about by the opening up of large tracts of land in America and Australia, have made a certain amount of engineering knowledge a matter of necessity, not only to the farmer, but also to the owner of property and his agent or clerk of the works. It is in the effective carrying out of the repairs on an estate that the greatest and truest economies can be effected. Perhaps few things have tended more to cripple the farmer, and consequently his landlord, in recent years than the failure of the deep system of drainage of twenty-five years ago, just at a period of exceptional and continued wet seasons. Again, how many farm-houses are built with no regard to the cost of their

maintenance, and how often do we see wood used where iron might be substituted once and for all. A visit to any large establishment in the colonies will impress the reader with the strict regard to economy in cost that is paid by the farmer to all matters requiring labour. The days of draining by eye and what is known as the practice of rule of thumb are gone by, and with the excellent survey of the Ordnance Department on the $\frac{1}{25}$ inch scale, there can be no more excuse for buried drains, whose exact locality dies out with the man that made them, or for work executed on an estate and not shown on the survey sheet. But to do this requires some knowledge of the use of engineering and surveying instruments, and some acquaintance with the practice of civil engineering itself. In the following chapters we propose to give such general engineering details, a knowledge of which is desirable, before executing the particular work referred to; and also such mathematical formulæ as are recognised as governing the question theoretically, with the intention that in that which the reader cannot calculate out, he may lay his case, and the formula given, before some person acquainted with that branch of mathematics; whilst the ordinary reader may make himself familiar with the general features of the case. In many cases, the approximate cost is given of executing certain works, but only as a guide. The price of labour, material, and the *quality* of the labour vary so greatly in different countries, that no law of prime cost could be laid down. As a general rule, it may be said that the labour got north of the river Trent is superior

to that in the south, treated as labour only. In the south less work is done in a day, but it is done thoroughly. In all mechanical work, the north-countryman is superior; a northern driver and breaksman on a goods train are soon recognised by railway men; but, for purely agricultural labour, the men from the south are as good. So that where machinery is used, a Lancashire or Durham man is the proper man to be in charge of it; the engine to him is what the horses and stock are to the man from the south. Where a thrashing engine is used the result of the plan will be that many a leaky tube will be saved, and waste of coal and oil avoided, and where reaping and binding machines are kept, when done with, they will be housed clean and fit for use, and the inevitable blacksmith's bill saved when the machine is next wanted for use. So also is it to be observed in the use of mortar and cement, in building operations, and more especially in the coping of walls and out-buildings. Bad or poor lime and improper mixing are the cause of constant pointing being necessary, and insufficient coping—*i.e.* the coping stones or bricks, as the case may be, not projecting far enough to protect the wall from drip in wet weather, is the certain means of destroying the wall ultimately. There is no more short-sighted economy than that of not spouting farm buildings and cottages. In the former case, the brickwork soon perishes, and is disintegrated by the action of wet and frost, and consequently has to be renewed; and in the latter case, the foundations of the cottages absorb the damp and moisture that should be carried away, making

the cottages unhealthy, and the tenants not only discontented, but liable to rheumatism and premature old age.

The construction of minor bridges and culverts will be a matter for grave consideration, and both when new and on their being reconstructed due regard must be had for the weight they will have to carry. Traction engines, constructed as they are to be handy in turning, are so short for their weight that care must be taken that the engine either does not stand entirely between the supports to the bridge, or that the supports are strong enough to bear the entire weight (*i.e.* three times the entire weight of the engine), it being desirable that no structure should be loaded to a greater extent than one-third its breaking or crushing load. Trivial as these precautions may seem, the Employers' Liability Act and the Boiler Explosions Act, and the increased liability that thereby falls on the employer, render it necessary for him to accept the position as one of greatly increased pecuniary responsibility, and by the excellence of his works and precautions to protect himself from consequences that are unfortunately inseparable at times from the use of steam and machinery generally. To that end we have given the substance of certain Acts of Parliament that regulate such questions, so that the employer may secure himself from liability. In the question of the dredging and embanking of streams, only such operations as one owner can with prudence undertake at his own cost are dealt with. To make an effectual alteration or improvement in the carrying power or direction of a river

is a work of some considerable magnitude, and should only be attempted as such by a Board or Commission, as in the case of the River Tees Improvements Commission. Much benefit may be derived in judicious banking and straightening, and in the removal of shoals, without incurring great expense. But in this, as in some other matters, very considerable harm may be done by the want of the technical knowledge necessary. Larger shoals may be formed by too high a velocity being given to the stream, by the injudicious removal of a bank of gravel or some such obstruction. The velocity of the stream must be so regulated as to be in accordance with the stability of the bed of the stream. The growth of weed in some places is to be encouraged to effect this under certain circumstances. The protection of mainland drainage outfalls into the stream is also a matter of great importance, and the choice of their site, and the extent and nature of their protecting works, is more an engineering than a purely agricultural question. Allied to this branch of the subject is the important one of water supply and analysis. Hardly one farmhouse is entirely satisfactory on this point; farmers still believe that anything that is water at all will suffice for stock, whereas such is distinctly not the case. Pure air and pure water are as essential to stock as to human beings. The widespread existence of hydatid cysts in the human being, as well as in the sheep, in Australia, is greatly to be traced to the necessity of tank-water being used on the stock routes, owing to the absence of water holes or streams. Where impurities exist is the seat of the germs of microscopical

animal life; in some cases their very existence is dependent on a supply of septic or putrefactive matter. With the increased knowledge that M. Pasteur and Professor Koch have given us of the bacillæ and bacteria, of anthrax and other diseases incident to animal life, greater care should be exercised in the supply of drinking water to stock. The necessity for completely isolating the subterranean spring water of a well from the surface drainage water is not realised yet in many parts of England, and it may be observed that not infrequently the one class of supply is mistaken for the other, until typhoid fever or diphtheria decides the point. In towns, water supply is one of the first questions of the day, and it is a noteworthy feature that one of the effects of civilisation is to make water a saleable commodity; all the more then should those that possess, gratis, the means of obtaining or distributing pure water to others avail themselves of the well-known laws of sanitary engineering to obtain and supply it pure. Here we see the great injustice of towns or factories polluting rivers. It is a defence (and more a political one than a true one) that certain industries are dependent on pollution of rivers, such as paper works, dye works, &c. It is maintained that were too strict a law passed prohibiting the pollution of rivers, the industry and *its labour* would be extinguished. The other side of the question is, no industry has ever been destroyed except by competition or want of demand. Pure water is part of the *rights of property*, and whilst industries and labour can go elsewhere, can modify their processes, and can utilise their refuses, the

supply of pure river water is regulated by the laws of nature. A long experience as consulting engineer to the Trent Board of Conservators has inclined me to the view that *absolute prohibition* of all pollution of rivers would be found the shortest way of dealing with the question. The present Act is entirely useless, as instanced by the case of Lord Norton *v.* the Birmingham Corporation (Pollution of the River Tame).

It is not clearly proved that any pollution is necessary. The *extent* of the works necessary to remove the pollution from the river is always urged in defence, if possible; but in reality it is a most eloquent argument that the pollution should cease, for had the injunction to cease been obtained long previously, the necessity for works of such extent and cost would never have arisen. This is the reason why every owner who suffers from a pollution should stop it at the outset once and for all, and not wait until it has assumed such proportions that the plea of extent and cost referred to can be raised as a defence. The practical result of the present Rivers Pollution Act is to partially sanction pollution, thereby removing all stimulus to scientific men to find means to deodorise and render useful and innocuous the sewage and waste products of factories in large towns. Apathy on the part of the landowner of the last generation has bequeathed the necessity and expense of sinking for pure water on his successor, and the writer can instance cases of wells being sunk to supply stock in *fields adjoining the river itself*, so greatly was the natural river supply polluted. Injudicious interference with the flooding of rivers with-

out first dealing with pollution will complete the list of fatal mistakes regarding the management of rivers in this country. The uses of lime, cement, and hydraulic cement in construction, are another important point where an experienced clerk of the works is not available. The actual planning and designing of buildings could not be dealt with here. It is essentially the work of an architect, and no general rule could be laid down. Every case of new buildings being required, or repair or alteration of existing ones, is, or rather ought to be, governed by the particular local circumstances, and to attempt to lay down rules for the guidance of those responsible for their erection, excepting, of course, such universally recognised rules as govern the stability of all structures and rigid bodies, would only mislead instead of guiding. Most leading firms of ironfounders have adopted patterns which give standard sizes for certain spans of iron roofs which are calculated to leave a wide margin of safety; but there are times when it is desirable to increase this margin, as in the case of an iron barn erected in a situation liable to sudden or cyclonic gusts of wind or heavy drifts of snow. As a general rule it may be said that the erection of farm buildings of any kind in an exposed situation is if possible to be avoided, even if some additional expense within reason is thereby incurred. In exposed situations, shelter is most often required, but it need not follow that the structure itself should be exposed. The same observations apply to agricultural machinery generally that apply to specific structures. The care of all classes of machinery is a

question of employing careful men. The selection of it is a more difficult matter. But the trials of the Royal Agricultural Society, and the opinion of agriculturists generally, are very reliable guides. In the purchase of a steam engine the opinion of an experienced engineer should be taken. The uses of a portable railway on estates are not recognised sufficiently in England, and some recent improvements have greatly reduced the first cost of the plant, and brought its repairs within the attainments of the local blacksmith. Where continual carting is necessary over clay land, work may be done by its means that could not be attempted with horses in winter, and employment thus found when, all agricultural operations being at a standstill, distress is prevalent, at a time when privation is most keenly felt. A question of frequent occurrence on an estate is the development of power by means of a fall of water. On this head several tables are given by which an approximate idea may be gained as to what power can be obtained from a given fall of water, or *head*, as it is technically called. The operation of retaining earth, cutting, filling, and other such works that may occur, either in forming reservoirs or making roads, are also tabulated in *days of a man's work*. Earthwork is always treated by both engineers and contractors in this way. From the labour required the cost is found, and it is to be noted that a very considerable saving is effected by properly proportioning the men engaged in 'getting' an excavation to the 'fillers' and 'wheelers,' or men engaged in filling and wheeling away the earth thrown out by the excavators.

Such general tables are given also as may be found necessary in the application of the engineering rules. Each subject is considered under its own head, on an elementary scale, with subsequent rules for its more advanced application.

CHAPTER II.

LEVELLING, AND THE USE OF THE DUMPY LEVEL.

On the Dumpy Level and Clinometer, and the General Operations of obtaining Sections and Levels.

THE *difference of level* between two points, or the *actual undulation at all points* along the line between the two points, is found by the use of the dumpy level. This instrument is practically a telescope so constructed that the spirit level attached to it and an imaginary line passing through the centre of the telescope and in the direction of its length—*i.e.* from eye-piece to object-glass—are in the same plane and parallel with each other. So that if the spirit level be laid true, the line of sight of the observer will also be true and level, when looking through the telescope. To lay the spirit level true, four milled headed screws are provided. To use these screws effectually, plant the instrument attached to the legs firmly on the ground. Turn the telescope gently round until the tube lies exactly over two of the adjustment screws referred to. One screw will be in front of the axis of the telescope, the other will be behind it, in the direction in which the observer is looking. Now turn the screw heads very gently either way until the air bubble in

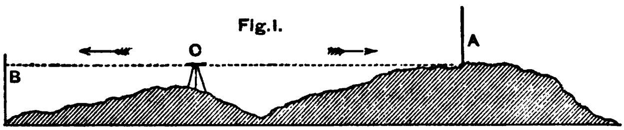
the spirit level comes to the centre of the tube and remains there. Slowly turn the telescope round until it points in a direction at right angles to the line to be observed. It will be seen that the tube now lies over the other two screws. Proceed as before with this pair of screws and reverse the telescope again to the former position, when the level has been obtained. The telescope will be found in all probability to be slightly out of level again. Repeat the whole process till the bubble remains stationary whilst the telescope is made to revolve the whole circle, returning to the original position. It is then in adjustment to use. These points are to be guarded against in the process. The approximate level of the instrument must not be got by the means of the plate screws referred to, for fear of straining them; the legs must be shifted so as to put the instrument level as near as the eye can tell; then the fine corrections by the process described may be made. The observer must also be careful that the weight of his body in soft ground does not disturb the level of the instrument without his knowledge.

Having thus placed the instrument level, we have, where extreme accuracy is required, to consider the curvature of the earth. The level gives the observer a line of sight in a horizontal plane, and it will be at once seen that if the object or staff observed is any distance from the observer, it is lower than the line of sight. This curvature is 7·962 inches per mile, or ·6635 foot. The line of sight is a tangent to this curve. It is only ·01 of a foot in a horizontal distance of 220 yards. The necessity for making the correction

is obviated by making the horizontal distance between the back and fore stations as nearly equal as possible when levelling. We now come to the practice of determining the difference of level between two stations, A and B, Fig. 1.

Set up the dumpy level at any point as nearly equi-distant from A and B, say at C. Place the dumpy level in adjustment for true level as previously instructed. Read the staff at A in feet, tenths, and hundredths of feet. Note it down as the *backsight reading* C A. Turn the telescope towards B. Instruct

Fig. 1.



the staff man at A to chain the distance A B on his way to B. Note the horizontal distance A C as he passes you. Read off the staff held up at B. Note it down as the *foresight reading* C B. The difference between the two readings at A and B is the difference of level. If the greatest reading is at B, then B is lower than A, and *vice versâ*. The dotted line in the figure represents the line of sight. In inclines, such as occur on roads and railways or in the preparation of sections, this difference of levels is usually given as 1 in so much. For instance, if the horizontal distance A B is 1,000 feet, the difference of level 5 feet, the incline is 1,000 divided by 5, or 1 in 200, that is, one foot of fall for every two hundred feet of horizontal distance. In levelling to get the *difference of level* between any two

points, the length of sight taken—*i.e.* the distances C A, C B—should never be made greater than 400 yards.

Before proceeding to describe the process of levelling to get a section of the ground, or a plan showing all its undulations, the chain and staff require some consideration.

The chain, known as Gunter's Chain, when spoken of without further qualification, is 66 feet long from outside to outside of handles. Each link is ·66 of a foot, or 7·92 inches. Gunter's chain is $\frac{1}{80}$ of a mile in length or ·0125, the square described on it being therefore $\frac{1}{10}$ of an acre, statute measurement. Ten 'arrows' accompany the chain. The proper way of using the chain is to engage two men, respectively called the 'leader' and 'follower.' The leader leads off from A, leaving the follower at A (Fig. 1); on the chain becoming tight he should turn and face the follower, who must direct him to the right or left, as the case may be, to ensure the direction of the line chained being straight; on the follower being satisfied this is the case, the leader stoops and puts down *one* arrow at the exact point where the outside of the handle of the chain comes to; having done this, he should call 'One' to the follower, and the two men should prôceed in the direction of station B, the leader dragging the chain and arrows, the follower having the field- or note-book, in which he enters the number of chains as called by the leader. When the follower arrives at the arrow planted by his leader he puts the handle of his end of the chain down outside it and touching it, and directs the leader as before, who calls Two' when planting his second arrow. The follower

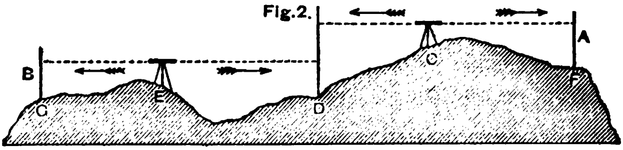
enters the number two in his book, and picks up number *one* arrow. At the end of ten chains proceeding thus, the leader should have no arrows, the follower ten, and ten chains should have been recorded in the book. Thus mistakes are avoided and time and labour saved.

The staff, as generally used, is thus made and read:—

The levelling staff is made in three telescopic lengths; from fourteen to seventeen feet in length, when all three lengths are extended, is found sufficient for ordinary use. Each foot is divided into tenths of feet, shown by the black figures on the staff, and these tenths are again subdivided into hundredths of a foot; the feet are shown in red Roman characters, so that five feet and twenty-five hundredths of a foot would read thus, v ·25. It will be observed that the staff and landscape appear upside down in looking through the level. This, with a little practice, is soon hardly noticed by the observer, but at first some little care is necessary to avoid making a mistake in the number of feet read off; it being to be borne in mind that the feet are to be reckoned from the base of the staff upwards, or, as it appears in the telescope to the observer, from the base downwards in the field of the telescope. In holding up the staff the staff-man must be careful to hold it steady and upright. The other appliances that may be used are the tape measure, and the 100 foot chain. The former is generally very inaccurate when wet, and the Gunter's chain is preferable in every way to it; the 100 foot chain is only useful for measuring earthworks and masonry.

We now come to the estimation of the undulation of the surface of the ground. The process is virtually the same as that explained by Fig. 1, but more extended. When the distance between two points is so great that the fore station cannot be seen, it becomes necessary to take a continuance of levels until the fore station is reached. To effect this, the same methods are to be observed as regards the preliminary adjustments of the instrument and the reading of back and foresights. Fig. 2 gives an outline of the actual sights to be taken.

Fig. 2.



Here the station B is not visible from A. Place the level at C; take the backsight CA; let the staff-man proceed to D; turn the telescope round and take the foresight CD; proceed with the level to E, leaving the staff-man at D; take the backsight ED; let the staff-man proceed to G, which is a convenient site at the station B; read the foresight EG. Then the backsight CF and the foresight EG are respectively the sights at A and B. Taking imaginary figures as an example for the field book, then suppose

Backsights		Foresights	
C F reads as .	. V·25	C D =	X·20
E D „ .	. III·05	E G =	IX·01
Total .	VIII·30	Fore =	XIX·31

Then the difference of the totals of back and foresights equals XI·01, therefore eleven feet and one hundredth

of a foot is the difference of level between A and B, and because the total of foresights is greater than the total of backsights, the station B is *lower* than A. If the total of backsights in the direction of A was the largest, then A station would be the lowest of the two stations. In practice it is well to select some permanent object, such as a wall, for the marks at A and B.

Where it is required to ascertain the height of any particular spot above *sea level*, the following is the means to be employed:—

Wherever the nearest and most convenient Ordnance Survey bench mark or broad arrow exists, erect the staff for a backsight; proceed as shown in Fig. 2 until the foresight reading at the spot itself is obtained. Ascertain the difference of level between the Ordnance mark and the spot, and add or subtract it to the corresponding reading in feet given on the Ordnance Survey sheet against the broad arrow shown on the sheet. This result is the height of the spot above Trinity high-water mark. If the spot is below the bench mark in level, the difference of level must be subtracted; if above, it should be added to the Ordnance reading. This is the process to be observed in adjusting barometers for height above sea level. The term *bench mark* is to be understood to mean the site of a principal observation; in Fig. 2, B represents a bench mark. These marks are defined by a broad arrow in Government surveys, usually cut on gate posts, bridges, or walls of buildings. Their object is to simplify any subsequent re-survey that might be found necessary, if an error occurred, and it is very advisable to inform

the Director-General of Ordnance Survey, Southampton, if it should be found necessary to remove or demolish anything on an estate on which a bench mark is cut. This is very frequently neglected.

The *level field book* is best ruled in columns, thus :—

Rise	Backsight	Foresight	Fall	Reduced Level	Distance	Notes

The first entry will be the reduced level of the bench mark obtained by the first backsight at A (viz. C A, see Fig. 2); the other entries will be the backsights and foresights as taken. The reduced levels are reckoned by adding or subtracting the rises and falls from the level of the first bench mark at A.

As a check, the total rise and total fall should equal the difference between the sum of the backsights and the sum of the foresights.

Plotting the section and datum line.—The datum line is a line drawn on the plan of the section with the

Fig. 3

horizontal distances marked. This line represents the route. It also is intended to be in vertical section the level above or below which the undulations of the ground vary. In plotting the section two scales are used—one, the horizontal scale of the datum line; the other the vertical scale.

Thus, in Fig. 3, A B is the horizontal datum line,

B C the dotted line, representing the section obtained along A B by levelling.

FINE ADJUSTMENTS.

There is one adjustment that may be required. It sometimes happens that by some accident the spirit level and telescope are not parallel to each other, so that when one is level the other is not. To correct this, bring the bubble of the spirit level to the centre by means of the plate screws. Lift the telescope out of its supports, called Y's. Replace it with the ends reversed. If the bubble does not remain in the centre and is disturbed, correct *one half of the error* by the platescrews, the remaining half by the small screws connecting the spirit level and telescope. If the bubble remains true in the centre, the instrument is in true adjustment, and the correction need not be made.

Levelling with the Barometer.—For rough or preliminary work the rise or fall of the barometer due to difference of level may be used to calculate the level. For draining or hydraulic work the dumpy level must be used.

The table on next page, assuming the barometer to stand at 30·00 inches at sea level, gives what is required, at 64° Fahrenheit.

Thus, if the barometer reads 30·00 at sea level and 27·4 in land, the place is 2,368 feet above the sea.

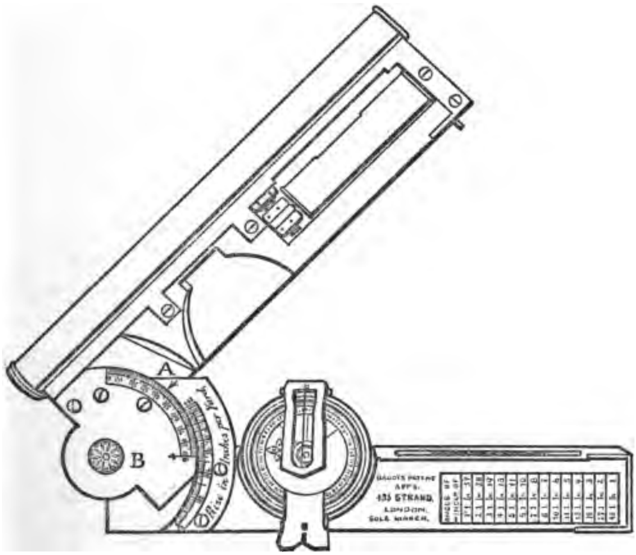
Levelling with the Clinometer for Trial Levels (Fig. 3).—With a view to simplifying the operation of taking preliminary levels, the writer brought out the above instrument. The instrument is first opened, the

TABLE OF FEET CORRESPONDING TO DIFFERENT BAROMETER READINGS.

Readings of Barometer	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
29	886	796	706	617	528	439	351	363	175	87
28	1,802	1,709	1,616	1,524	1,432	1,340	1,248	1,157	1,066	976
27	2,753	2,656	2,560	2,464	2,368	2,273	2,178	2,084	1,990	1,896
26	3,739	3,638	3,539	3,439	3,340	3,241	3,143	3,045	2,947	2,850
25	4,763	4,659	4,554	4,452	4,349	4,246	4,144	4,042	3,940	3,839
24	5,830	5,721	5,613	5,505	5,398	5,291	5,185	5,079	4,973	4,868
23	6,942	6,829	6,716	6,603	6,491	6,380	6,269	6,158	6,048	5,939
2	8,103	7,985	7,867	7,749	7,632	7,516	7,400	7,285	7,170	7,056
21	9,319	9,195	9,071	8,948	8,826	8,704	8,583	8,462	8,342	8,222
20	10,593	10,463	10,333	10,204	10,076	9,948	9,821	9,695	9,569	9,443

lower limb being laid level by its spirit level in the universal holder provided on the staff, and then secured by the clamp in that position. The upper limb, on which the telescope is mounted, is then gradually raised or lowered until the cross hairs in the telescope cut the staff or surface of the ground, as the case may

FIG. 4.



be. The brass scale is then read thus. The arrow A reads off the angle of inclination; the arrow B the rise in inches per yard; thus, if the instrument be opened till the arrow A reads 45°, the angle of inclination, the arrow B will show an incline of thirty-six inches per yard, or one in one. There are several other uses to

which this instrument is applicable in trigonometrical surveying and measuring altitudes.

The important points in all levelling operations are accuracy and precision. There are many means of checking the results obtained; amongst them the one that commends itself is the carrying on a projection of he line levelled to an Ordnance bench mark at each end. A reduction and comparison of levels will check the whole line of levels taken. Levelling may be effected by means of the theodolite, but it is not usual except under very peculiar circumstances. The tangent of the angle subtended by the top of the ground and the clinometer, multiplied by the length of the base line in feet, is the height in feet of the object above the instrument. If a tangent table be not at hand, the tangent of 45° is one, so that if the clinometer be removed till 45° is subtended, the base line is equal to the perpendicular or height required to be found.

In levelling along a canal it is to be borne in mind that the correction for curvature is to be most carefully made.

These are all the most important points in the general practice and theory of the level. In railway operations, levelling is a specific practice; being more used with a view to calculating the cubic contents of earthworks to be removed, or embankments formed.

Where the practice of levelling is required to be extended to such matters, an engineer's opinion and observations are desirable, the foregoing chapter being only intended to give such information as can be used by the land agent or clerk of the works.

CHAPTER III.

THE THEODOLITE AND PRISMATIC COMPASS; AND THE MEASUREMENT OF VERTICAL AND HORIZONTAL ANGLES.

On the Theodolite, Prismatic Compass, and Clinometer, and the Operation of Trigonometrical Surveying and Determination of the Superficial Areas of Triangles and the Measurement of Vertical Heights.

FOR this purpose—*i.e.* the taking of angles, whether vertical or horizontal—the theodolite is usually employed. The angles are called 'azimuths' when in a *horizontal* plane; if in the *vertical* plane they are called 'altitudes' or 'depressions.' The transit theodolite is in all respects the most useful of these instruments. The instrument is set up in the usual way as regards level; the revolution of the upper dial-plate on the lower measures the angle taken as follows. The upper dial-plate and the telescope are in one piece; the lower dial-plate is fixed to the base of the instrument. If the clamping screw that fixes the two dial-plates in a rigid position is loosened, the upper plate, or dial, and telescope will revolve on the lower plate, which will remain fixed. The circle being divided into 360 degrees, it is clear that the arc through which the telescope revolves will be shown by

the difference of the readings on the two dial-plates and their scales. Thus, if both dials read 0° at starting, the compass being true north—*i.e.* the telescope pointing north and south at 0° on the dial scales—then if an object be observed at due east, the upper plate, when turning the telescope to observe the object, will have travelled through an arc or part of a circle amounting to 90°. That object is then said to be 90° east of north. The telescope may then be brought to bear on another object, bearing, say 182°, or to the west of south, to another say 275°, or to the north of east. Suppose those three points to be the three points whose relative positions to the compass we require; then we have to draw pencil lines at angles of 90°, 182°, and 275° on the Ordnance sheet to give the relative direction of the objects. The exact point is got by chain from the observation station, the length of the horizontal line observed. It is not necessary that the theodolite shall be true north and south. The angles may be taken as from 0°—that is, the horizontal angle subtended between the instrument itself and the object—not between the object and the meridian.

The use of the instrument to its full capabilities can only be acquired by extensive practice under a surveyor. Areas can be got from the 25-inch Ordnance survey, or books of areas. The principal use of the theodolite is in setting out the main lines of new buildings, or in measuring vertical heights.

The trigonometrical properties of a triangle are as follows:—

$$\text{Sine} = \frac{P}{H} \qquad \text{Secant} = \frac{H}{B}$$

$$\text{Cosine} = \frac{B}{H} \qquad \text{Cosecant} = \frac{H}{P}$$

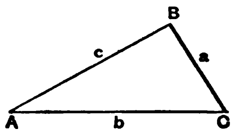
$$\text{Tangent} = \frac{P}{B} \qquad \text{Cotangent} = \frac{B}{P}$$

$$\text{Versed sine} = \frac{H - B}{H}$$

$$\text{Coversed sine} = \frac{H - P}{H}$$

when B is the base, P the perpendicular, and H the hypothenuse.

The areas of triangles require a knowledge of trigonometry, and are more accurately obtained by laying the triangle down on paper and proceeding thus:—



$$\text{Area} = \frac{b \times c \times \text{sine of angle A}}{2}$$

$$= \frac{ab \text{ sine C}}{2}$$

$$= \frac{ca \text{ sine B}}{2}$$

If $S = \frac{1}{2}$ sum of the sides of the triangle, then

$$\text{Area} = \sqrt{S(S - a)(S - b)(S - c)}.$$

The Right-angled Triangle.

The hypothenuse $= \sqrt{\text{base}^2 + \text{perpendicular}^2}$
The base $= \sqrt{\text{hypothenuse}^2 - \text{perpendicular}^2}$
The perpendicular $= \sqrt{\text{hypothenuse}^2 - \text{base}^2}$

PROPERTIES OF THE CIRCLE.

Diameter	×	·3·14159	=	circumference
„	×	·886226	=	side of an equal square
„	×	·7071	=	„ inscribed square
Diameter ^{2}	×	·7854	=	area of the circle
Radius	×	6·28318	=	circumference of the circle
Circumference	×	·31831	=	diameter of the circle

These details may be found convenient to refer to in taking horizontal angles and measurements with the theodolite.

The question of taking *vertical angles* of slopes and heights next presents itself. To this end proceed as follows:—Erect the theodolite level; clamp the two horizontal dial plates fast; bring the telescope and its spirit level parallel to the level of the plates—*i.e* all spirit levels are to stand level. The theodolite should read 0° in this position on the vertical scale. Now observe the top of the object with the telescope. The angle read off on the vertical arc scale is the angle subtended—*i.e.* the angle formed by a line drawn from the top of the slope or height meeting the horizontal level line produced by the line of sight when the telescope is level. The tangent of this angle multiplied into the base in feet gives the height in feet of the perpendicular; the angle itself is the angle of the slope, or hypothenuse.

The prismatic compass is practically a theodolite laid in the magnetic meridian. The angles subtended are the angles formed with the meridian. It is principally of use for military surveys, or in its modified form, the miner's dial, for underground mineral surveys.

The clinometer is also adapted for angular measure-

ments for preliminary surveys and road construction. The following tables are given for reference in the preparation of sections of levels and horizontal surveys. In building or architects' plans the scales are more liberal. When the plans to be drawn are intended to show the courses of house-drains or hydrants, or water-supply, the scale of one inch = 10 feet is the most desirable for estate work.[1] The main angular bearings should be taken by the theodolite from some central spot that commands them and the details chained in. An example of this is shown at the end. Every house let to a tenant should have the reference plan of drains supplied; and it may not be out of place to remark here that a landlord may be made liable in a civil court for damages and compensation if he lets his house to a tenant in an insanitary state as regards water supply and drainage; and I am afraid that recent decisions on that point will cause considerable grounds for complaint amongst tenant farmers and cottagers if landlords do not pay increased attention to the question.

Some special features are more fully treated in the chapter devoted to Sewerage and House Drainage, to which the reader is referred.

The care of the theodolite when not in use is of great importance. It should be handled carefnlly aud well dried after use, and kept in a dry place. The delicacy of the instrument is such that any fine adjustments are best made by the maker. A six-inch transit instrument is the one best suited for the work. In using a pris-

[1] This work is thoroughly executed by the Ladies' Tracing Office, 8 Great Queen Street, Westminster.

matic compass, if the observer wears spectacles in a steel frame, let him beware of deviations arising therefrom in the compass readings.

For more applications of the instruments above described the reader is referred to the 'Manual of Civil Engineering' (Rankine) and the 'Treatise on Military Surveys' (Col. Basil Jackson).

The cost, exclusive of expenses paid out, of a survey are:—

Surveyors' Charges.

Surveys of estates to show gross contents and boundary only:—

	£	s.	d.
For the first 100 acres	7	10	0
For each extra acre	0	0	9
Contents of farms, for first 100 acres . .	10	0	0
,, ,, ,, each extra acre . .	0	1	0
To show fields and buildings, first 100 acres .	15	0	0
Each additional acre	0	1	6
Minimum rate charged by a surveyor per day	3	3	0

Vertical Scales for Sections.

Vertical Scale	Fraction of Real Height	Suitable to a Horizontal Scale of	Use
100 feet = 1 inch	$\frac{1}{1200}$	$\frac{1}{15840}$ to $\frac{1}{10560}$	Smallest scale for sections of works allowed by Parliament
40 ,, ,,	$\frac{1}{480}$	$\frac{1}{4800}$ to $\frac{1}{3960}$	Do. for cross-sections, showing alteration of roads
30 ,, ,,	$\frac{1}{360}$	$\frac{1}{3960}$ to $\frac{1}{2376}$	Scales suitable for working sections
20 ,, ,,	$\frac{1}{240}$	$\frac{1}{3960}$ to $\frac{1}{2376}$	

TABLE OF SCALES.

Scale	Fraction of Real Dimensions	Suitable for Use for
1 inch to 1 mile .	$\frac{1}{63360}$	Smallest Ordnance Survey
4 " " .	$\frac{1}{15840}$	Smallest scale for proposed works (deposited Parliamentary plans)
6 " " .	$\frac{1}{10560}$	6-inch Ordnance Survey. Suitable for general preliminary work of a large amount
6·336 " " .	$\frac{1}{10000}$	Decimal scale, same as above
25·344 " " .	$\frac{1}{2500}$	Latest Ordnance Survey (25-inch) to be used for all estate work, such as drainage, &c. The square of 1·0018 inch = 1 acre. The area of each published sheet of this survey is 960 acres

CHAPTER IV.

RAINFALL.

On Rainfall, and its Influence on Land Drainage.

THIS is a point generally entirely neglected by the farmer. Without proper observations on the average rainfall, land drainage becomes a mere process of guess work. The source of all water supply is rain. The more mountainous the country, the greater the rainfall, and the more uncertain in character. The steady character of the rainfall in the Fen district round Boston, in Lincolnshire, is due to the level state of the country, there being nothing to induce condensation. In England, the prevailing winds being from the west, the western portion of the country has the greatest rainfall, but it is to be observed that more rain falls on the eastern side than on the western side of a range of hills.

The total recorded rainfall is not the available rainfall. The latter will be less than the former.

The records required from the rain gauge are :—

i. The least annual rainfall.
ii. „ mean „ „
iii. „ greatest „ „
iv. How distributed at various seasons, and especially the greatest drought.
v. The greatest flood rainfall, or continued fall of rain.

For water *supply*, i. and iv. are the particulars wanted.
„ drainage, iii. „ v. „ „ „

The rain gauge suited to the work consists of a copper cylindrical vessel 10 inches in diameter, and about 15 inches high. This is fitted with a funnel-shaped mouth, ending in a pipe 8 inches long. A measuring glass receives the rain passing down the pipe. To test the accuracy of the measuring glass, pour into the gauge a known weight of water and note the height it stands in the glass; to perform the correction—

One cubic inch of water = 252·6 grains of water at 62° F.
„ foot „ = 62·355 lbs. „ „

The glass measure being divided into cubic inches, the reading divided by the area of the funnel in square inches will yield the depth of rain in inches.

The gauge should be freely exposed, and sunk in the earth to prevent evaporation and its being accidentally knocked over. It should be read every morning. One should be kept on every estate. Without such record, no engineer can advise either as to water supply or drainage. The neglect to keep such a record frequently is the cause of useless and expensive drainage works being executed, when half the outlay perhaps might suffice were it available for the engineer's inspection.

The rainfall in England per annum varies from 22 to 150 inches; the least recorded annual depth being 10 inches.

The dampness of the air—that is to say, the amount of water it holds in suspension—is obtained by the hygrometer, a wet and dry bulb thermometer. The reductions of rainfall are—

Inches of rainfall	× 2,323,200	= cubic feet per sq. mile.	
" "	× $14\frac{1}{2}$	= millions of gallons per sq. mile.	
" "	× 3,630	= cubic feet per acre.	
1 cubic inch of water		= ·03612 lbs.	
1 gallon of water		= 10 lbs.	
" "		= ·16 cubic foot.	
1 ton "		= 35·9 "	
" "		= 224 gallons.	

From the experiments made by Schrœder on the power of various classes of soils to absorb moisture from the air, the following results were found :—

	Tons per Acre	Equal to a Rainfall	
Light clay . . .	26	·256	in inches.
Medium clay . .	30	·296	in inches.
Stiff " . . .	36	·355	in inches.
Vegetable mould .	45	·444	in inches.

The area over which rainfall is distributed is called the '*Catchment Basin.*' This basin is determined by the natural configuration and slopes of the ground. It is defined by the fact that all rainfall within it is collected and delivered in the same direction. It is in fact a drainage area. A large catchment basin is usually subdivided naturally into a number of smaller ones, regulated by the existence of water ridges, each emptying by its own stream into the main stream. An important exception to this rule, that the boundary of a catchment basin or drainage area is a ridge line, is when a porous stratum exists, allowing the rain water to disappear. Therefore, in levelling to find the ridge line, a geological map should be consulted always.

Available Rainfall.—This is that proportion of the total rainfall that remains for the purposes of water supply, or to be drained away when the amount of rain absorbed by the soil added to the quantity

necessary for the life of the plants growing, and the quantity lost by evaporation is deducted from the total, observed by the rain gauge. If the total rainfall from the roof of a house be taken as 1, then the amount of *available* rainfall for different soils would be represented proportionally thus:—

Moorland and hills pasture from	. ·8 to ·6
Flat cultivated country from .	. ·5 to ·4
Chalk	. 0

Deep springs and wells yield from ·3 to ·5 of the total rainfall as available rainfall. In some exceptional cases the yield is even greater than ·5.

The following table illustrates the general application of rainfall to the supply of water per head of the population on a scale showing the size of catchment basins for town supplies.

WATER SUPPLY AND DRAINAGE AREAS.

Discharge required		Number of Population		Gathering Ground	Reservoir
Cubic Feet per Minute	Millions of Gallons per Day	Number at 30 Gallons per Head	Number at 50 Gallons per Head	With Stream delivering 8 C. Feet per Sq. Mile	To hold Water for Four Months at 53 C. Feet per Minute
				Sq. miles	Millions of c. feet
27·8	·25	8,333	5,000	3·48	4·88
55·7	·50	16,666	10,000	6·96	9·70
83·5	·75	25,000	15,000	10·44	14·65
114·4	1·00	33,333	20,000	13·93	19·53
139·2	1·25	41,666	25,000	17·41	24·42
167·1	1·50	50,000	30,000	20·89	29·30
195·0	1·75	58,333	35,000	24·37	34·18
222·8	2·00	66,666	40,000	27·85	39·07
250·7	2·25	75,000	45,000	31·33	43·95
278·5	2·50	83,333	50,000	34·82	48·84

The second table gives the quantity of water that is produced by a given amount of rain over a given area. This table is the one that will be found most frequently necessary to refer to.

QUANTITY OF WATER DUE TO A GIVEN RAINFALL OVER A GIVEN AREA. CATCHMENT AREA IN ACRES.

	On 1 Acre	On 2 Acres	3	4	5	6	7	8	9	On 1 sq. Mile
Rainfall in Inches	In Cubic Feet	In Thousand Cubic Feet								In Million Cubic Feet
1	3,630	7	11	14	18	22	25	29	33	2⅓
2	7,260	14	22	29	36	44	51	58	65	4⅔
3	10,890	22	33	44	54	65	76	87	98	7
4	14,520	29	44	58	73	87	102	116	131	9¼
5	18,150	36	54	73	91	109	127	145	163	11½
6	21,780	44	65	87	109	131	152	174	196	14
7	25,410	51	76	102	127	152	178	203	229	16¼
8	29,040	58	87	116	145	174	203	232	261	18½
9	32,670	65	98	131	163	196	229	261	294	21
10	36,300	73	109	145	181	218	254	290	327	23¼
12	43,560	87	131	174	218	261	305	348	392	27¾
15	54,450	109	163	218	272	327	381	436	490	34¾
20	72,600	145	218	290	363	436	508	581	653	46½
25	90,750	181	272	363	454	544	635	726	817	58
30	108,900	218	327	436	544	653	762	871	980	69¾
40	145,200	290	436	581	726	871	1,016	1,162	1,307	93
50	181,500	363	544	726	907	1,089	1,270	1,452	1,633	116¼
60	217,800	436	653	871	1,089	1,307	1,525	1,742	1,960	139½

Thus, with a rainfall of 4 inches over six acres, the quantity of water caught amounts to 87,000 cubic feet.

The next table will also be found necessary to refer to.

These details will have to be referred to in drainage operations continually, and it is to be understood that to establish the boundaries, or ridge lines, of a drainage

Discharge due to Rainfall in Depth from 2 to 60 Inches per Annum.

Rain per Annum	Cubic Feet per Minute		Cubic Feet per Day		Gallons per Day	
	For 1 Acre	On 1 Sq. Mile	For 1 Acre	On 1 Sq. Mile	Per Acre	Per Sq. Mile
2	·013802	8·83	19·87	12,720	123·8	79,245
4	·027604	17·66	39·75	25,440	257·6	158,491
6	·041406	26·50	59·62	36,160	371·4	237,736
8	·055208	35·33	79·50	50,880	495·2	316,982
10	·069011	44·16	99·37	63,600	619·0	396,228
12	·082813	53·00	119·25	76,320	742·9	475,473
14	·096614	61·83	139·12	89,040	866·6	554,718
16	·110416	70·66	159·00	101,760	990·5	633,964
18	·124219	79·50	178·87	114,480	1,114·2	713,210
20	·138022	88·33	198·74	127,200	1,238·0	792,456
22	·151824	97·16	218·62	139,920	1,362.0	871,701
24	·165626	106·00	238·50	152,640	1,485·8	950,947
26	·179427	114·83	258·37	165,360	1,609·5	1,030,193
28	·193228	123·66	278·24	178,080	1,733·2	1,109,438
30	·207033	132·50	298·12	190,800	1,857·0	1,188,684
33	·2277	145·73	327·90	209,851	2,042·8	1,307,372
36	·248438	159·00	357·75	228,960	2,228·7	1,426,420
42	·289842	185·50	417·37	267,140	2,599·8	1,109,437
48	·331252	212·00	477·00	305,280	2,971·6	1,901,894
54	·372657	238·50	536·62	343,440	3,342·6	2,139,630
60	·414066	265·00	596·25	381,600	3,714·0	2,377,368

area, preliminary levels must be taken across the farm both north and south, and east and west; but it will be often found that by planting the level in a central position, sights may be got all over the farm, and the configuration of the ground thus rapidly established. As a general rule it will be seen that there is usually a distinct slope in a given direction on the farm, caused by the natural effect of the flood discharge. Before attempting any drainage operations on a large scale, these laws governing the extent and effect of a fall of rain must be considered thoroughly, with a view to

its being decided *how much* water falls over *that extent in area* in a given time, and per annum. The next chapter deals with its *removal* by draining. The greatest rainfall in England in 24 hours is about 3 inches; the mean daily evaporation in the same time being ·08 of the rainfall. Infiltration being:—

In winter	33 per cent.
In spring . . .	35 ,,
In summer . . .	2 ,,
In autumn . . .	48 ,,
Average of the year .	=42 ,,

CHAPTER V.

DRAINAGE OF LAND.

On the Drainage of Land, and Surface and Subsoil Systems, and the Quantities and Dimensions of Materials used, with Contract Forms necessary.

THE removal of the excess of water in the soil is effected by drainage. The size and number and width apart of the drain pipes is determined by the result of the observations described in the preceding chapter on rainfall. The operation of levelling has been already explained. Drainage of land may be classed under the following heads:—

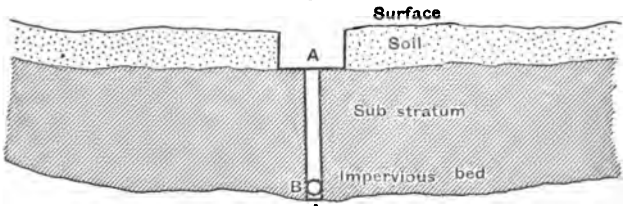
I. Subsoil drainage.
II. Upper „
III. Interception „

Subsoil drainage is the deep drainage of the strata underlying the soil. If the soil is light and rests on impervious, or water-bearing strata, the rainfall passes through the soil, and rests on the top of the impervious stratum, or floods the water-bearing stratum. The upper soil then becomes soaked like a sponge. Draining the upper soil will not prevent this to anything like the extent that draining the subsoil will do; the

work of subsoil draining may appear heavy, but in reality there is much less of it to be performed. The labour is partly that of excavation, and filling in afterwards. Subsoil drainage in general precedes upper drainage; the foundation for the upper soil is first made secure and sound, and then the excess of water removed by upper drainage. The necessity for subsoil drainage is best established or not by proceeding to tap the underground strata with trial holes, in dry weather, but after rain.

To effect this, remove a space of the supersoil, say 2 feet square and 1 foot deep; bore a hole through

Fig. 5



the remainder of the upper soils till the substratum is reached.

Thus in Fig. 5 it will be seen that the water that filters through the soil is pent up in the substratum, because the substratum rests on an impervious bed that will not allow it to escape through; the result is that unless an escape for it be provided by a drain pipe B, it will 'boil up' as it is called, and ultimately saturate the soil; and the unfortunate feature in the case is that this always happens after a wet season, and

perhaps just when the land has a chance of getting dried. The necessity of laying down the subsoil drain B is shown by whether the water in the trial hole A A stands in it to any height. The holes should be examined 48 to 56 hours after they have been put down. From the section given it will be seen at once that no amount of draining the upper soil would remedy the case. The effect of such subsoil drainage is to increase the temperature of the upper soil from 1° F. to even as much as 3° F. It will also be noted that there is less hoarfrost deposited on fields which have their subsoil well drained; this is due to the lesser degree of exhalation from the surface being condensed, and so deposited again on the surface. These two advantages greatly tend to stimulate the growth of the crop and the efficiency of the soil in regard to its germinating properties. Much *alleged* defective surface drainage is really due to deficient or inefficient subsoil drainage. The grave mistake of putting deep drainage out to contract in *one* contract, that was almost universally committed thirty years ago, and especially in the drainage works executed with Government assistance, repayable over a term of years, is the cause of heavy expenditure on the part of the landlord now. Subsoil drainage is most essentially a landlord's affair, and may be classed as a permanent improvement. Let it be clearly understood, therefore, that the essential point in drawing up any drainage contract is that the *cutting or excavation work* shall be a contract with one set of men; the laying of the pipes (and delivery if desirable, on the spot) shall be a contract with

another set, the landlord's own men if possible, and the filling in not executed by contract at all. These measures ensure accuracy of level, and that the pipes are not disturbed by careless filling in. If the work be let in one contract, the frequent results are that the pipes are 'put out of sight as quickly as possible' and the landlord ultimately is disappointed.

But when subsoil drainage was introduced in 1835, it was a clearly accepted point that it should be followed by subsoil ploughing. Where this was practised it succeeded; but in many cases, and more especially latterly, it has been neglected. This is particularly the case in Needwood Forest, which furnishes an example. Here the subsoil is a stiff yellow clay; in places patches of red marl rest upon it, but the general subsoil is a cold clay. When it was disforested some ninety years ago, subsoil drainage was not understood. Thirty years ago it was laid down, in most cases that have come under my knowledge, very inefficiently. At first, when the upper soil contained old turf and vegetable matter formed from the leaves of trees, &c., excellent crops were raised. The greatest local prejudice then existed to breaking up the subsoil, and no wonder. The upper soil being now worked out and the subsoil never broken up, the existing soil is saturated by absorption, resting as it does on a subsoil of undrained marl and coarse gravel, which is itself resting on this bed of stiff and impervious clay. Upper drainage is resorted to, and frequently fails. Where the subsoil drains run, if any exist, is forgotten, and the tenant farmers are afraid to

stir the subsoil, ploughing thus being limited to a depth of 7 to 9 inches. In a wet season the crops are very bad and the pasturage like a sponge. But had deep subsoil ploughing been practised immediately after the subsoil drainage, the vegetable mould would have been incorporated with the upper soil, which would have thus been increased in depth and porosity, and which would have rested on a drained foundation.

The first crops would not have been as heavy, but the average would have been good and lasting, and the present state of the land avoided. As it is, any improvement on the part of the farmer is rendered abortive till the subsoil is freed of water. But even then the depth of soil is gone for good, and must be artificially replaced by careful farming.

The filling in of a subsoil drain should be done under the superintendence of a foreman. Where stones have been thrown out in excavation, they should be laid carefully on the top of the drain, and if the course of the drain intercept any spring, for the space of 12 feet on either side of the spring it will be found very advantageous to fill in for the first 20 inches with gravel or broken tiles. To fill in with clay renders the drain useless. By filling in the first 20 inches with loose material, the subsoil water penetrates the drain quicker, and the drain is said to 'draw' further—*i.e.* to collect water at a greater distance on either side of its course.

The width apart of the subsoil drains is greatly governed by the porosity of the strata, but in such soils

as require deep draining the following may be taken as a guide:—

In very light water-bearing strata . . .	30 to 33 feet apart
In light clays with gravel . . .	25 „ 30 „
In medium clays and marls . . .	22 „ 24 „
In stiff impervious clays . . .	18 „ 20 „

In special cases it may be found necessary to reduce this width to even as little as 5 feet.

The *estimation of the work* is the next question that presents itself. To this end the length of drain pipes that will be required to drain one acre is to be ascertained from the following table:—

SUBSOIL DRAINS.

Length of Drain Pipes required in the Statute Acre.

No. of Feet Apart	Length in Feet	Length in Rods of 16½ Feet
5	8,702	527·3
6	7,262	440·1
8	5,445	330·1
10	4,350	263·6
12	3,631	220·0
15	2,900	175·7
16½	2,640	160·0
18	2,421	146·7
21	2,073	125·6
24	1,815	110·0
27	1,614	97·8
30	1,450	87·8
33	1,314	80·0
36	1,210	73·3

The carriage of the drain pipes is calculated thus. The table gives the number of pipes of different bores or diameters that can be put in one cart drawn by one horse. One man is allowed for each pair of carts.

EACH PIPE BEING 12 INCHES IN LENGTH.

Diameter of Pipe	Weight	Number in a Cartload
1 inch	11¼	950
2 ,,	16½	700
3 ,,	34½	400
4 ,,	44½	380
5 ,,	72	350
6 ,,	102½	160
7 ,,	123	140
8 ,,	161	90
9 ,,	181	75

AVERAGE COST OF DRAINING TOOLS.

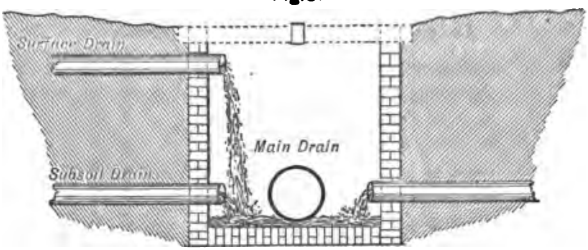
	s.	d.
Ordinary spades, each . . .	5	6
Mattocks, each	5	0
Narrow draining spades, each . .	8	0
Drawing scoops, each . . .	4	6
Pushing ,, ,, ...	4	6
Shovels, each	3	9
Stone picks, each	7	6
Common picks, each . .	5	0

The fall and course of the drains must be decided by the nature of the soil, &c. A sharp fall is very desirable in subsoil drains, where it can be obtained; they are less liable to become choked.

The direction is marked out for the excavators in a line by means of stakes, the rate of fall or section is entrusted to the foreman, and the actual depth from the surface of the drain at each stake is painted on the stake as a guide; at certain sites, such as junctions, it is necessary to have inspection shafts constructed, which also serve as air escapes, and allow the air contained in the drain to escape when compressed by a heavy volume of water descending the drain; if these escapes be not provided, the drain is liable to be blown up.

These inspection shafts should be brick, laid in cement, 1 part cement to 3 of sand, 2 ft. 6 in. × 2 ft. square, Fig. 6. A lead label, with the description of the drains or numbers corresponding to the indication on the drainage plan punched on it, should be securely fixed over each drain pipe delivering into the shaft. The shaft is closed by an iron grate or flat stone (Yorkshire flag), but if the latter a small hole should be put

Fig. 6.



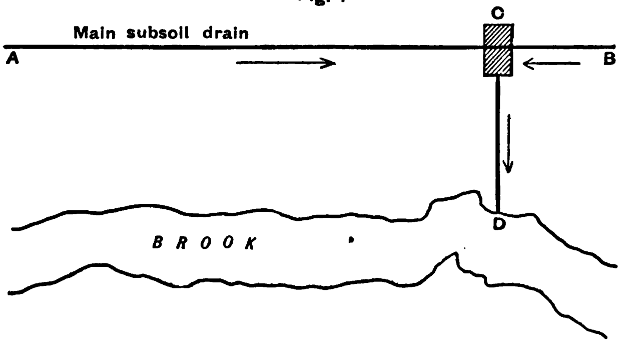
through it. These shafts are a very great saving of expense in ascertaining the conditions of the drains, or gauging the flow. The efficacy of subsoil drainage is estimated by the diminished annual average flow, gauged in the man-hole or inspection shaft, after comparison with the total rainfall.

It is essential that the discharge pipes delivering into the inspection shaft should project not less than 3 inches from the brickwork. In very wet localities, or in running sand, it may be found necessary to provide 'weep-holes' or apertures between the bricks of the retaining lining wall of the shaft to prevent it being damaged by the wet at the back.

An important advantage is gained, where the levels

of the surface admit of it, by providing cross relief drains. Thus in Fig. 7, which represents the horizontal plan of a subsoil drain A B approaching near the bend of a stream C D, lower in level than A B. A B may be relieved of pressure by the drain C D cut across to

Fig. 7



intercept A B. Care must be taken to observe the maximum flood level at D, lest the water from the stream should back up into A B.

The relief system is only useful in long drains by reducing the diameter required for them and so reducing the cost, and increasing their efficiency by providing additional outfalls.

When the excavators have dug the trench, the level is again taken, and the trench corrected where required. The pipes are then laid and their level taken. Filling in is then practised.

The engineer notes, by means of the theodolite, the direction of the drains; by the Gunter's chain the distances from conspicuous objects are ascertained.

Outfalls of Main Drains.—These should be in selected sites. In some cases it is better to deliver into a man-hole, the overflow being allowed to flow into the stream. This is the case where the banks are undermined by floods; the general rule is to protect the outfall pipe by brickwork in cement, and if necessary by flanking works.

Fig. 8

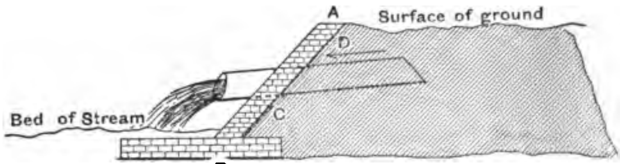


Fig. 8 represents the section of such outfall. The face A B should be well thrown back and the masonry provided with outlet pipes or weep-holes at D and C. It should rest on a good footing at B so as not to be undermined by its own delivery of water. This plan is to be strictly adhered to in all outfalls. The writer has seen outfalls entirely obliterated for want of such works, which should, in the case of a pond, be protected from the tread of cattle drinking.

Subsoil ploughing is effected either by steam or horse power. It is purely an agricultural operation, generally to be performed by contract. Steam is preferable for large fields, horse power is necessary for small ones. The relative cost cannot be compared except on the spot. All things being equal for both the quality and cost of the work, the difference is every year more in favour of steam. It should (if by steam)

form the subject of a contract, the details of which should ensure a proper average depth, a limit of time taken in the operation, and the removal of couch-grass or twitch and large stones brought to the surface by the subsoil plough.

It may be observed here that the main subsoil drain into which the other deep drains empty should be laid with a view to efficiency of outfall in wet and after continued wet weather, and with every convenience as regards direction, diameter, and fall, to enable ultimate extension. A practice exists of planting willow trees to bind the banks of the stream at the outfall. This is most objectionable. When willow roots extend within 50 feet of subsoil drainage, they should be either avoided by diverting the course of the drain, or cut down, and their roots grubbed or destroyed by pouring vitriol on the stumps. If this is not done they will ultimately choke the drain pipes entirely.

It need hardly be observed that attention is to be given to the porosity of the pipes. Their quality is shown by their 'ring,' or resonance when struck. In transit by rail 7 per cent. should be allowed, in ordering, for breakage, 2 in carting, 2 in unloading and laying, in all, 11 per cent. for breakage from the works to the spot they are required on. Pipes with a 'dead ring' should be rejected. They are liable to become rotten and decay.

The foreman in charge of the work should have a plan and section of the work, and daily record on it the work done. In flat, level land, the curvature of the earth is to be allowed in levelling.

A most useful table for discharge from pipes running full for a given *fall* where the pipes are of a given *diameter* is subjoined. It is a table of constants to avoid excessive labour in calculation. If *half the constant number* be taken, instead of the whole, the results are very nearly those for pipes running *half full*, and as drains should have a margin of carrying power to that extent, the result thus obtained is what is required. The table is further applicable to find the *diameter required for the pipes* and the fall necessary to accommodate a given discharge of rain fallen. Example. What will a pipe discharge that is 6 inches diameter and 2,000 feet long?

$$\frac{2000}{20} = \text{fall of 1 in 100, then } \sqrt{100} = 10,$$

and constant number $\frac{416\cdot5}{10} = 41\cdot65$ cubic feet per minute.

DISCHARGE OF PIPES (IN FEET CUBE PER MINUTE).

Diameter of Pipe In.	Constant. To be Divided by the Length of the Pipe Fall	Diameter of Pipe Ft. In.	Constant. To be Divided by the Length of the Pipe Fall
1	4·71	7	612·32
1¼	8·48	8	854·99
1½	13·02	9	1,147·61
1¾	19·15	10	1,493·47
2	26·69	11	1,894·93
2½	46·67	1 0	2,356·00
3	73·50	1 1	2,876·68
3½	108·14	1 2	3,463·32
4	151·02	1 3	4,115·93
4½	194·84	1 4	4,836·87
5	263·87	1 5	5,628·48
6	416·54	1 6	6,493·14

Rule for Discharge.—The length (l), fall (f), and

the diameter (d), being known, C, the number of cubic feet per minute discharge is :—

$$C = \frac{\text{square root of } f \text{ or rate of incline}}{\text{corresponding constant in table.}}$$

Diameter of pipe required = P

$$P = \text{sq. root of } f \times \text{discharge.}$$

Find the nearest corresponding constant in the table. The diameter opposite to it is the required result.

Fall required.—Divide the constant for the given diameter by the discharge. Square the result, and divide it (the result) by the length of the pipe. The result is the head or total fall required to drive the quantity of water through the pipe.

Note.—All terms to be taken in lineal or cubic feet.

Bends.

Bends in the course of the pipe should be as few as possible and in parabolic curves. Their resistance causes loss of head—viz.,

V = velocity in feet per second.
H = head necessary to overcome the friction.
A = angle of bend.
$H = \cdot 0155\ V^2\ K$.

The value of K is

For an angle of	20°	K =	·046
„	60°	„	·139
„	80°	„	·364
„	90°	„	·74

For an angle of	100°	K	=	·98
„	120°	„		1·26
„	150°	„		1·86

In surface drainage these tables are equally applicable. It may generally be assumed that subsoil drains run half full, but their actual discharge may be gauged in the man-holes referred to.

Having freed, by the operations described, the substratum of its water, the surface soil may require shallow drains, to keep the soil from becoming puddled and impervious; to effect this properly, the drains should lie at a depth from the surface that prevents them from being crushed in by steam engines or disturbed by the plough or in trenching.

Their depth and width apart is further governed by the nature of the soil, the existence or not of effective subsoil drains, and the natural slope of the land. Except the soil be dry the action of manure is wasted. On a saturated soil no benefit can be obtained from the action of lime.

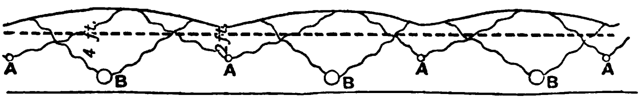
Before finally deciding on the shallow drainage of a piece of land already provided with subsoil drains, the attention of the reader is directed to the subsequent question of interceptive drainage. There may arise occasions on which a skilfully directed interceptive drain, across the natural slope of the land, may intercept and carry off the water that would otherwise drain itself away by following the natural slope of the land.

The cases we have to consider are those where such

a drain is not serviceable or practicable, rendering it a simple matter of surface drainage only.

It may be on the whole best in most cases to place the drains in the natural water-furrows where arable land has been laid down to grass. The quality of the grass in these water-furrows is poor, and the drainage will greatly improve it, and thus add to the 'keep' of the field; further, it accelerates the *rate* of drainage after heavy falls of snow; thus Fig. 9 shows the section of a field so drained, and Fig. 10 the field in plan.

Fig. 9



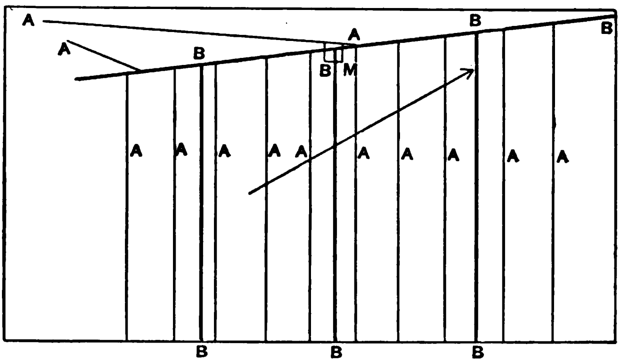
Section.

The dotted line is the depth of the cultivated soil, or the point at which the substratum commences. The drains marked A are the surface drains, those marked B are subsoil drains. The waved lines illustrate the sectional area of ground drained by both—*i.e.* the respective 'draw' of the drains. M is a man-hole and air escape.

In Figure 10, the arrows show the general incline of the field. In this case, supposing the field not to have been provided with subsoil main drainage and main drain, it would be necessary to provide a heading-drain across the surface drains for them to empty into. To empty surface drainage into ditches, in the boundary fence, it is necessary to bring the drains too close to it. They become choked after a time, and are greatly

interfered with when their outfall is choked by snow-drifts. This is more especially the case on the north and east side of the fence. The writer has had experience of them being the cause of very nasty falls in the hunting field, the drains breaking in on the horse alighting.

Fig. 10



The same field in plan.

The levelling to be carried out for such surface drainage is confined to the taking of the necessary levels to ensure a proper fall for the main drain. The diameter of a main surface drain should never be less than six inches. Sub-mains may be four inches diameter; branch drains, three, two, one-and-a-half inches.

The *fall* is calculated from the preceding table of constants thus. The rainfall is gauged for the area of the whole field, as total rainfall, and the maximum fall in a given continuous period also noted. The result is that the minor drains will discharge, or should dis-

charge, that amount at a certain rate into the main drain. Then, having determined that rate and quantity, or discharge, reference is made to the table of constants for discharge, and it will be at once seen that the question comes under the first application of it. The level having been taken for the main drain, it is seen what is the total amount of *available* fall. Taking this as the fall we have to use, the number of cubic feet the main drain will accommodate, on the proposed scale, is ascertained by the application of the table of constants as directed and shown by the example; but for convenience sake another case is shown here.

The main drain is 3,000 feet long and 6 inches diameter.

The total available fall is 20 feet.

Then $\frac{3,000}{20} = 1$ in 150 inches.

The square root of 150 is 12·247.

The constant for a 6-inch pipe, 416·5.

416·5 ÷ 12·247 (omitting the decimal readings)
= 34 feet cube per minute.

Then the discharging power of that proposed main drain is 34 cubic feet per minute, *running full.*

The only question to decide then is, is there a sufficient margin of carrying power? As the drain should never run more than half full, the carrying power is in practice only 17 cubic feet per minute. If the total maximum rainfall does not exceed this, and does not come up to it by 20 per cent. the drain is large enough and the fall is sufficient.

The discharge for a given rainfall over a known area is given at the end of the chapter on Rainfall.

Having found the efficiency of the main drain, to find the efficiency of the small furrow drains, add up the sum of their diameters; treat this result as the size of one pipe—*i.e.* its diameter. Proceed, as in the case of the main drain, to find the maximum theoretical discharge in cubic feet per minute; if the rainfall observed is only 60 per cent. of this amount, the proposed surface drainage works are sufficient, and the whole works properly proportioned on a well-established engineering basis. It is to be borne in mind that the discharge in *practice* will be only half the volume of the maximum theoretical discharge, as the pipes should not run more than half full.

Thus—10 3-inch diameter drains each 200 feet long.

Total available fall 10 feet.

Rate of incline = 1 in 20.

Required the discharge (max. theoretical);

then—10×3 = total diameter of pipes,
= 30 inches (for one pipe),
10×200 = total length (of one pipe),
=2,000 feet.

It then simply becomes necessary to proceed as previously shown by the table of constants for discharge from pipes.

No rule is to be laid down for the rate of fall for surface branch drains. It is the most fall that can be got economically and safely that ensures the pipes

delivering into the main drain. The less the fall the greater the number of branch drains and the larger their bore. The point to be aimed at is to rid the soil quickly of the excess of rainfall. The velocity of any falling body is $8{\cdot}04\sqrt{\text{distance fallen}}$. In the example previously given, the total fall was given as 10 feet.

Then 8 times the square root of 10 feet
$$= \text{velocity of water in feet per second,}$$
bends, friction, and obstructions not allowed for.

The square root of 10 is 3·162; leaving out the decimal readings,

$$8 \times 3 = \text{velocity in feet per second}$$
$$= 24 \quad \text{,,} \quad \text{,,}$$

Allow $\frac{1}{6}$th, that is 4 feet per second, of the total velocity to be absorbed by friction, &c., then 10 feet fall yields 20 feet velocity per second.

Too great a fall makes too heavy a pressure on the pipes themselves, and may burst or blow them up. The pressure is directly as the height, or total fall called the head of water. It may be taken generally that 30 feet of water = 1·5lbs. per square inch pressure on the pipe, so that *excessive fall* is to be avoided.

This may be done in several ways; by means of man-holes the pressure may be relieved, or by deviation slightly in an oblique course across the line of natural slope, thus lessening the velocity of the water by absorbing it in friction going round the curve, but care must be taken how sharp the curve is made, or the pipes will be displaced; a man-hole may be placed

at the curve if too sharp with advantage. The above tabulated results are collated from contracts made in different parts of England. They are a mean index to cost. A considerable series of drainage contracts were executed by Mr. Robert Brown, and with so nearly the same results that it may be taken as a reliable guide to estimate the cost of work of this nature. In the Midland Counties, except the coal and iron trade is depressed, the cost is from 4*l.* to 7*l.* per cent. higher than that given in the table. In *all* cases the main outfall drain is to be carried out first, and the work proceeded with up, and not down, the incline. Collared pipes are advisable for six inch and larger diameters, and the trench for the pipes should not remain lying open for any length of time, before the pipes are laid. The bottom may require ramming firm. A case is given of the cost of draining running sand. The bed was 3 feet 9 inches deep to the solid clay. It had to be drained at any cost, and not with open trenches, for special reasons. As a rule, running sand is best drained by wells sunk vertically. No pipes must be laid in running sand; they must be laid on the top of substratum of solid material below it, which causes the sand to run.

It will generally be observed that the presence of high ground, near the site of the running sand, storing a quantity of water, is the cause of the great quantity of running water in the sand.

In Northumberland Avenue, London, the thickness of the bed of running sand to be sunk through to the London clay is over 40 feet, or 42 feet at the north end

TABLE OF NUMBER OF PIPES REQUIRED TO DRAIN ONE ACRE.

	Width of Drains Apart	Depth	No. of Rods of Drains per Acre	Cost of Cutting and Filling per Rod	Do. per Acre	Number of Pipes 1 Foot long required per Acre	Cost of Tiles at Thirty Shillings per 1,000	Total Cost per Acre
Soils of a Heavy Type:	ft.	ft. in.		s. d.	£ s. d.		£ s. d.	£ s. d.
Stiff clay and gravel . .	15	2 6	176	0 5	3 13 4	2,905	4 7 2	8 0 6
Do., adhesive .	16½	2 6	160	0 4¾	3 3 4	2,640	3 19 2	7 2 6
Friable, do. .	18	2 9	147	0 4½	2 15 1½	2,420	3 12 7	6 7 8
Easy clay . .	21	2 9	126	0 4	2 2 0	2,076	3 2 3	5 4 3
Medium Soils:								
Clay loam . .	22	3 0	120	0 5	2 10 0	1,980	2 19 5	5 9 5
Marl ,, . .	24	3 0	110	0 4½	2 1 3	1,814	2 14 5½	4 15 8
Gravelly loam .	27	3 0	98	0 7	2 17 2	1,613	2 8 4½	5 5 6½
Friable ,, .	30	3 3	88	0 6	2 4 0	1,452	2 3 6½	4 7 6½
Light Soils:								
Gravelly loam .	33	3 6	80	0 8½	2 16 8	1,320	1 19 7	4 16 3
Marly ,, .	36	3 9	74	0 8	2 9 4	1,209	1 16 3	4 5 7
Sandy ,, .	39	4 0	68	0 7½	1 19 8	1,117	1 13 6	3 3 2
Very easy ,, .	42	4 0	63	0 7	1 16 9	1,037	1 11 1½	3 7 10½
Sandy soil . .	45	4 0	59	0 7	1 14 5	974	1 9 2½	3 3 7½
Running sand .	8	to solid clay	—	—	—	5,460	special rate	16 10 0 minimum

of Westminster Bridge. In cases of this sort, foundations are obtained by the process known as sheet piling. That is to confine the water in the sand by driving down flat piles to, and well into the solid substratum, thus ensuring the area required. On this area the building is erected. The writer once had occasion to make use of piles to carry a main drain through running sand, which should receive the water. Wrought-iron pipes were used, screwed into each other in ten-foot lengths. The piles were driven in every 20 feet, and the pipes supported on them. In places the pipes were perforated to allow the water entrance, the last pipe of the lengths of iron pipe discharged into a catch pit to remove the sand that entered with the water. The results have been quite satisfactory, as previously to this even brush wood drains had been carried away laterally at times. The depth of the bed of sand was 6 feet to 8 feet in places, being a band 90 feet wide.

It may perhaps be well to state here the causes of failure in both subsoil and surface drainage that the foreman in charge of the work will especially keep his eye upon when the respective contracts are proceeding, and a short draft form of agreement between the contractor and engineer is given, a modification of which may always be made, which brings the matter into a proper business shape.

Memorandum of an agreement made on
18 , *between* A. B. . . . *and* C. D., *hereinafter called the Contractor.*

Whereby the said C. D. undertakes to execute the

following works and to complete and deliver the same on or before the day of 18 , or in default of such delivery to pay the sum of 2*l.* per day.

(Here insert the specification of works to be executed thus.)

1. *To excavate the entire horizontal course of the main drain, marked* (1) *on the plan, in a thorough and workmanlike manner, and in such a manner as shall preserve and render efficient the levels and rate of inclination described and shown on the sectional plan attached.*

(Following this, the remainder of the works to be executed are inserted, ending always with the proviso :)

'*The said* C. D., *the Contractor, further engages to carry out the above works to the satisfaction of the said* A. B., *his engineer or agent, for the sum of £ s. d. on the understanding that no part of the works specified and executed shall be paid for that are not carried out and executed in accordance with the plans and sections attached, and to the satisfaction of the said* A. B., *his engineer or agent.*'

In witness thereof,

(Signed) A. B.
C. D.

Date .

N.B. The usual agreement stamp, according to the value of the agreement, should be affixed, or the contract may be drawn on stamped paper, to be obtained from the supervisor of Inland Revenue. The contractor should sign the plan and section on the plans referred to.

In many parts of England the excavation work is let out in rods of 16½ feet in length, at so much per rod, to individual labourers, but it is not a practice that is conducive to either good or careful work as regards rate of inclination, and it is most desirable to leave such sub-contracts to the contractor, and thus have only one man of some ability and pecuniary substance to deal with.

The points the foreman of the work will have to notice are:

That the rate of inclination is truly kept by the excavators; if not, immediately to stop the work, and having found the error, with the dumpy level, or clinometer, to see that it is rectified.

That the bottom on which the pipes are to be laid is firm.

That the earth excavated is thrown far enough to be clear of the trench.

The sooner laying and filling in can follow the excavation the better.

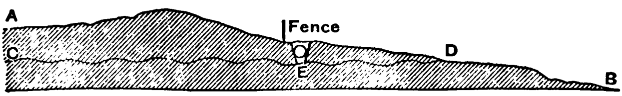
The foreman is particularly enjoined to take the levels on the staff held on the pipes every 50 feet to compare with the rate of inclination given in the section. The top of the drains should be well covered with stones, broken tiles, or other porous substances, to prevent their efficiency being reduced by the impervious nature of the soil immediately surrounding them.

These constitute the general features of the two operations of subsoil and shallow, or surface drainage. It may appear to the reader that these precautions and

methods of procedure are too extensive or too complicated. I can only urge that the *want of them* has cost the landowners in this country a very great deal more than they are yet aware of. There is only one systematic plan on which the excess of rainfall can be economically dealt with; that plan is based on the principle in hydraulic and civil engineering generally, that a given rainfall in a given time over a given area yields a given discharge, that its removal is governed by the diameter of the pipe and its rate of inclination. The directions laid down here are the practical application of that rule in the simplest and shortest way that an extensive experience in draining has recommended as being within the knowledge and requirements of those whom it is intended to benefit, and who have occasion to go into the subject continually.

The interception of water on the crests of slopes, and the drainage of bogs and swamps, next claim attention.

Fig. 11



Section.

In Fig. 11 A B represents two fields A E, E B. The line A B represents the general slope of the ground. The substratum is overlaid in A E by a bed of water-bearing or porous strata. At D the water boils up and floods D B. To drain D B is merely to flood E D and incur great expense. A trial hole is put down at E,

with the result that it promptly fills. A 4-inch or 6-inch drain is laid at E, sloped to give sufficient fall across the natural slope E B. By this operation the water blowing out at D is intercepted at E, and E B is drained thoroughly 'by there being nothing to drain,' as expressed by the Irish navvy. The water that falls over the area of the field A E is entirely carried away by the drain at E, and the necessity of E B being drained is removed.

This feature of interception, whenever possible, should be especially carefully studied in extensive drainage works. The writer intercepted for 11*l.* outlay a discharge estimated at 44*l.* by the tenant, which he proposed to carry off by surface drainage on the herring-bone system of laying the branch pipes.

Interception should form the first consideration to the engineer in planning a system of drainage. A very great number of the failures, of surface drainage more especially, have been due to want of interception at suitable places. It may occasionally be found that, in winter and spring time, ponds rise to a level that admits of the water escaping through the porous strata that lies above their summer level, and percolating out at some lower level. Disused marl pits that have become ponds are especially liable to have this form of escape for their winter flood discharge.

The drainage of *peat mosses* is a very simple, yet but rarely thoroughly understood, operation. It is spread over a period of some three to five years to be effective afterwards and economical at the time. Peat beds range from four to twenty feet in depth. As the

peat becomes drained it *sinks*; the water having left it, it contracts in all directions, but only that portion in vertical height from the bottom of the drain to the top of the peat does so. It, so to speak, floats on the surface of the undrained portion which still retains its excess of water.

The moss is staked out in plots of say ten acres.

Cross open ditches are cut 50 yards apart; parallel or 'end on' drains, in the form of open trenches 2 feet deep to begin with, are cut to empty into the cross drains at right angles. Each parallel drain is 21 feet from the next, so that there are 10 parallel drains to the acre. The effect is that the water contained in the section of the bed of peat 700 yards × 2 feet deep is squeezed out by the rain, and runs away into the cross drains. The whole system of drains, when the section referred to is dry, say in twelve to eighteen months, is lowered another 2 or 3 feet, when the same effect described repeats itself. This process is continued until the bottom of the bed is reached; after the second lowering the bed will bear cultivation with safety, as a rule.

Drain pipes may ultimately be laid along every third cross drain on the solid bottom.

The slope of all drains cut in peat should be as 3 to 1—*i.e.* 3 feet wide at the top for 1 at the bottom for 3 feet deep. This yields an average subsidence of from 9 to 12 inches when the peat is drained. The cost of such work may be reckoned at from 6*l.* an acre for mosses from 5 to 8 feet deep, and from 7*l.* to 12*l.* per acre when the depth ranges from 8 to 12 feet,

beyond which depth reclamation for cultivation is not recommended, and structures should be floated on the moss by judicious distribution of their weight.

If pipes must be laid through a peat moss, their weight must be distributed by placing them on planks $\frac{1}{2}$ to $\frac{5}{8}$ of an inch thick. The wonderful antiseptic properties of the peat water will preserve these planks for a hundred years or more.

To ensure success in the whole operation it is most desirable only to excavate the drains to such a depth as their sides will stand.

The reduction in the supporting and floating power of the peat as it drains may be well estimated by placing a large stone on the surface two yards or more from a drain. As the drainage proceeds the stone slowly disappears to a certain point beyond which it will not sink. Then the effective power of the drains has ceased and they must be deepened. Cattle crossings across the trenches should be sloped to 1 in 12; bridges often cause accidents to young stock and horses; cross planks may be laid with advantage in the ford, weighted at the ends with heavy stones. With the weight thus properly distributed horses cannot get bogged. A road over the moss is to be similarly treated.

The Liverpool and Manchester Railway was carried over Chatmoss by utilising the dry peats on fascines and hurdles, to form a sort of raft on which the railway floated. The weight of dried peat is 31 lbs. per cubic foot. One cubic foot will absorb 32 lbs. of water, thus weighing when saturated 63 lbs.

A curious and unexpected feature in the behaviour of peat mosses is that, if stones are tipped into them in a horizontal direction across the moss, they distribute themselves according to their natural slope; thus in extreme measures a road may be formed.

Swamps are somewhat similarly treated as peat mosses. Their depth decides their value for reclamation. They can frequently be greatly reduced in area first by interception. Recent microscopical research indicates that their margins are the haunts of some protoplasms, or organic germs, highly destructive to animal life. Their presence on a farm on which any head of sheep are kept is most undesirable for this reason.

Hill pastures are best drained by open courses as regards economy, but pipes are more efficient to produce a good quantity of the finer grasses so essential to good keep.

Generally the presence of the following plants and signs denotes an excessive saturation of the soil or ineffective drains. Rushes, especially if on the slope of the ridge of pastures; willow weed in arable land; a dark brown patch in places on pasture land; a falling off in patches of cereal crops in average length of straw on arable land, frequently very early in the season—indeed the rabbits are frequently credited with creating this appearance near the fences, which on examination proves to be defective drainage. The actual biting of the blade is to be looked for in the latter case. I may here observe that much is to be learnt of the saturation of the soil by using a percolation gauge. This gauge consists of different sizes of

porous earthenware cylinders. They are sunk to different depths in the soil, and the amount of water that finds its way in, in a given time, represents the necessity for further drainage or not.

These cylinders have been admirably constructed for me by Messrs. Johns & Co., of Armitage Pottery Works, Rugeley, Staffordshire, and are comparatively inexpensive. Other types of percolating gauges may be constructed; the advantage of this one is that the chemical constituents of the water caught may be examined effectually. The foregoing, then, forms the basis on which drainage works should proceed. If the rules laid down are carried out I am confident that the results predicted will follow, whilst after the lapse of any number of years the efficiency of the work can be tested, and its depth, position, and direction known, without the expenditure of a single penny. Such, unfortunately, has not been the case in times gone by. Several cases have come within my knowledge, as an engineer, where the landlord is paying drainage interest on drains long previously useless, whose depth and site is unknown, and where information respecting which could not be got without very great expense being incurred.

Reclamation drainage works are dealt with under the head of their necessary embankments in the next chapter on the treatment and control of rivers.

CHAPTER VI.

THE EMBANKING OF RIVERS AND THEIR GENERAL TREATMENT.

On the Embanking, Straightening, and General Treatment of Rivers and Water Channels, with Tables of the Labour thereon, and on the Construction and Protection of Outfalls to Main Drainage.

THE improvement of the natural channel of a stream, and the protection of the adjacent land from floods, is entirely dependent on the manner in which the proposed work is treated. The writer's experience as consulting engineer to the Trent Board of Conservators is that it has been the exception for river improvements to be carried out properly; indeed on several occasions so great was the harm that would arise, that he had to stop the work proceeding. No doubt it is very annoying to be told that the proposed work will do more harm than good; but perhaps the agent will feel consoled at the reflection that hydraulic engineering is so special a branch of civil engineering, that an ordinary civil engineer would probably take a special opinion before attempting the improvement of a river, and be convinced that, except the laws that govern the subject be studied, failure is the result. Let me cite an instance: a mill tail race was undermining the sup-

ports of a bridge at one end by washing away the gravel. The agent's attention was drawn to it. He allowed the matter to remain in *statu quo* until a hole 10 feet deep was washed out. The mill was then stopped, and after allowing the tail race to run down, the hole was filled in to the spring of the arch of the bridge with concrete; by this time he had entirely forgotten the existence of the trout and grayling in the stream, which were dying for want of water, until finally two fishery inspectors were despatched to the spot. The whole of this expensive and utterly useless operation might have been avoided by driving into the bed of the river a few short piles to divert the wash of the tail race, so that a load or two of gravel emptied into the race above the bridge would have been washed into the hole, and the hole filled up at next to no cost. It is this sort of work that does so much mischief to a stream, and the plain reason of it is that the work is done without any regard to any laws that may govern it, and without either the necessary skill or knowledge.

The particulars given in this chapter are not intended to extend to the larger operations on a main river, that are generally (if they are to succeed) vested in the hands of a Board of Commissioners; they apply to the rectifying and general works necessary on the minor tributary streams. Firstly, then, it is to be understood that notice to repair, raise, or alter any weir or river dam, or to obstruct the stream in any way, must be given to the Conservators of the Fishery District; that the raising of a weir renders the work of construct-

ing an efficient fish pass obligatory on the owner. To totally obstruct the stream is illegal. Where lime is used, the owner should have a man constantly present to see that it is not allowed to flow negligently into the stream, or, as is frequently the case, that the men do not purposely destroy the fish in the stream with it. The Rivers Pollution Act and Freshwater Fisheries Amendment Act deal with this effectually if these two points are neglected. The Salmon Acts 1861 to 1873 deal with free passes and obstructions.

The above are the points, then, that are to be noted if the place is within a fishery district.

The Stability of the Channel.—Before commencing straightening or other improvements that affect the velocity of the current, the stability of the bed of the channel must be estimated and secured. The term stability means that the materials that compose the bed of the channel are firm and cannot be disturbed or carried away by the current.

De Buat's Table of Stability.

For Current the Velocity of which is taken on the River Bed.

Material Composing Bed of Channel	Will bear a Velocity of
Soft clay	0·25 feet per second
Fine sand	0·50 „
Coarse sand and fine gravel .	0·70 „
Gravel (the size of beans) . .	1·00 „
„ 1 inch diameter . .	2·25 „
Pebbles 1½ inch „ . . .	3·33 „
Heavy shingle	4·00 „
Soft rock, brick, earthenware .	4·50 „
Various kinds of rocks . .	6·00 to 8·50 „

On the head of stability it may be said that a

stream with earthen or muddy banks and bottom is just stable, and no more, in minimum level. In flood or maximum level it is unstable at once. A river may be stable as regards its bed and yet unstable as regards its banks, or the exact reverse. Unstable portions of both banks and bed will be found here and there. It is these portions that claim the attention of the engineer. The bed of a river in an unstable condition is recognised by the existence of ridges of gravel or other material that have a long ascending slope on the upper side, and a sharp pitch down on their lower side, or side below, in the direction of the current. The ridge is formed first by gentle floods piling up the stones where the current happens to be slack; they are then pushed over the crest of the ridge and fall down the steep slope, gradually forming a shoal. The deep side of a shoal (and the dangerous side to wade when angling) is always the upper side after floods; especially is this so in the rivers Blythe and Dove and parts of the Trent, on account of the variable stability of their beds. The stability being governed as shown by the velocity as regards the bed of a channel, it is evident there must be more than *one* velocity.

There are three velocities—viz. that on the bed of the stream referred to in the preceding table of maximum velocities within stability over beds of different materials; that in the centre of the stream at the surface, measured from bank to bank; and that against the banks themselves. The *mean velocity* of a stream is obtained at any given cross section by dividing the

volume of flow in cubic feet by the area of the cross section in feet. The following table shows the comparative relations of the surface, bottom, and mean velocities in inches.

TABLE OF COMPARATIVE RIVER VELOCITIES.

Surface	Bottom	Mean
4·0	1·00	2·50
8·0	3·342	5·67
12·0	9·00	12·50
20·0	12·055	16·027
24·0	15·194	19·597

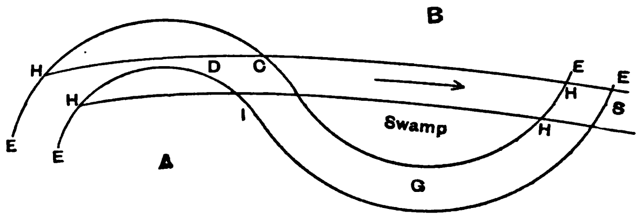
The velocity of a river is greatest at the surface and the centre, diminishing gradually towards the bottom and sides.

Anything which narrows the width of the channel will increase the bottom velocity, and a shoal will form lower down the river where the accelerated velocity becomes diminished.

Injudicious banking or protection to banks, the too free use of groins or wash-boards, may divert the current too violently to the opposite side of the river and damage or wash away that bank. In this case, if it is a different owner, it often happens that he places a counter wash-board on his side and throws the wash back again lower down; this state of things continues till either a lawsuit arises, or, more fortunately for both parties, if in a conservancy district the engineer interferes by removing the offending boards and straightening the channel fairly by taking an equal amount of land from each party, thus Fig. 12.

A and B are engaged in what may be termed a 'banking war.' A line H C H and H I H are surveyed in such a manner that what land is taken from A is given to B and *vice versâ* in the counter bend. Then H H H H is the new channel in place of E E E E, and the controversy set at rest to the mutual satisfaction of both

Fig. 12.



Plan.

parties. But levels must be taken to ascertain what effect the increased velocity will have on the bed of the new channel; if too great, it will be disturbed and carried away and deposited lower down in the direction of S.

The rule to ascertain the velocity of the current for such straight channels and for rivers generally of medium dimensions is subject to the *hydraulic mean depth* being first ascertained of the channel. The hydraulic mean depth is a technical expression for the sectional area of the channel divided by the length in girth in feet of that part of the channel, both sides and bottom, that is in contact with the water flowing in the channel. The quotient, in this numerical operation, is called the *hydraulic mean depth*.

The exact formula used is, for the friction, when

A = sectional area of channel.

B = its girth (above described) in contact with water.

L = length of channel so that $L \times b$ = its frictional area.

m = $A \div b$ or the hydraulic mean depth.

$$F = f\frac{L\,b}{A} = \frac{f\,L}{m}$$

F is the coefficient for friction.

For ordinary purposes the hydraulic mean depth in feet is multiplied by twice the fall in feet per mile. The square root of this result is to be multiplied by 55. The result is the mean velocity of the stream in feet per minute.

The next point is the rise of the river due to placing obstructions in it, such as piers of bridges. These results from careful experiments are given in table on next page.

The question of *embanking* can now be gone into. It is divided into the protection of river banks from the undermining action of the water; the erection of a system of protection by banks during times of flood to low-lying adjacent land, and their drainage; and sea or tidal defences. Reservoir banks are dealt with in a later chapter, under the head of Hydraulics. When a river passes through low-lying land thus, as in Fig. 12, embankments are resorted to for the purpose of confining the flood waters.

The embankments A A should be placed at some

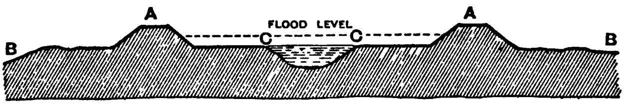
PIERS IN RIVER BEDS.

Amount of Obstructions Compared with the Vertical Section of the River.

Velocity of Current in Feet per Second	1-10th	2-10ths	3-10ths	4-10ths	5-10ths	6-10ths	7-10ths	8-10ths	9-10ths	
	Proportional Rise of Water, in Feet and Decimals									
1	Feet 0·0157	Feet 0·0377	Feet 0·698	Feet 0·1192	Feet 0·2012	Feet 0·3521	Feet 0·6781	Feet 1·6094	Feet 6·6389	
2	0·0277	0·0665	0·1231	0·2102	0·3548	0·6208	1·1995	2·8377	11·7058	Ordinary floods
3	0·0477	0·1144	0·2118	0·3618	0·6107	1·0687	2·0580	4·8850	20·1504	
4	0·0760	0·1822	0·3372	0·5759	0·9719	1·7008	3·2755	7·7750	32·0720	
5	0·1165	0·2792	0·5168	0·8782	1·4895	2·6066	5·0202	11·9160	49·1535	Violent floods
6	0·1558	0·3736	0·6912	1·1807	1·9925	3·4868	6·7154	15·9398	65·7518	
7	0·2078	0·4983	0·9221	1·5750	2·6578	4·6511	8·9578	21·2626	87·4780	
8	0·2678	0·6423	1·1884	2·0299	3·4255	5·9947	11·5454	27·4042	113·0422	Unusually violent floods
9	0·3359	0·8054	1·4903	2·5566	4·2956	7·5172	14·4777	34·3646	141·7541	
10	0·4119	0·9877	1·8276	3·1218	5·2680	9·2190	17·7551	42·1440	173·8440	

considerable distance from the natural banks at C C. Especially is this to be done if in any part of the river a bend occurs that may be utilised as a store reservoir to accommodate the flood waters. The land A B on either side may then be drained by a low-level dyke, and by pumping the drainage water back into the river by windmills, hot air, or steam, or occasionally the economic transmission of power by electricity may be

Fig. 13.



Section.

found applicable to the purpose, or, preferably to any of these methods, the dyke may be continued in a direction somewhat parallel to the course of the river until sufficient fall is obtained to turn the outfall of the dyke into the river. In taking levels with such an object in view the greatest accuracy is necessary, and the correction for curvature of the earth applied (*see* Chap. II.). If the embankments are raised too near the natural banks of the river, they must be very much higher. The material taken from the drain is to be applied to form the bank.

The construction of such an embankment is governed entirely by the nature of the materials at hand to form it. It should be three feet six inches higher than the highest recorded flood level. If no low-level dyke is required, then the material may

obviously be taken with great advantage to the object in view and with economy also from the strip of land A C, on either side, or on one side only as the opportunity occurs. The base of the embankment should be three times its height, the width at the top being one-third of the height. The materials suited to form such an embankment are dry clay, well rammed in layers one foot thick, earth, or any soil of considerable weight and stability. If peat, to be weighted with heavy stones and constructed in two-feet layers. Slopes of one and a half to one, or two to one are admissible for moderate pressures. The bank is to be protected, when necessary, by dry stone pitching down its face. These stones are to be roughly squared by hand, eight inches in thickness at the top of the embankment and increasing in thickness at the rate of three inches per yard. At the foot of the bank they should rest on piles or other secure foundation, according to the nature of the soil they rest on.

When A C (in Fig. 13) is sixty feet in length the cost in decimals of a day's labour of forming such an embankment per cubic yard will be :—

EMBANKMENT LABOUR TABLE.

Excavation and filling . . . . =	·0666 to ·0833
Pick work in heavy ground . . . =	·0333 to ·0416
Levelling and work on embankment .	·0333 to ·0416
Wheeling soil 30 yards run . . .	·0133
Total cost per cubic yard . .	·14 to ·18

If the embankment is to be turfed, the cost of the labour per square yard in decimals of a day's work will be :—

TURFING LABOUR TABLE.

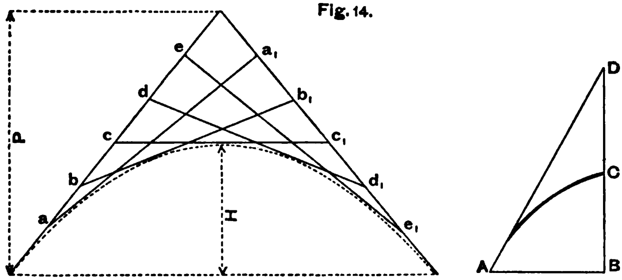
Paring turf and placing in barrows . .	·0833
Wheeling 20 yards run (each) . . .	·0133
Laying turf	·0833
Total cost per superficial yard . .	·18

If the turf has to be brought from a distance, the number of 20 yard runs in the total distance × ·0133 is the decimal labour reading for wheeling.

The next question is the construction of jetties, the protection of curves, and the alteration of direction in an embankment.

The latter had better be taken first, as reference may have to be made to it here in actual practice.

Fig. 14.



Inasmuch as a particle striking a plane surface has a tendency to fly off at a tangent, and the path of a moving body, when deviating or if deviated from a straight line by gravity is in the form of a parabola, it is clear that to deviate a stream by means of an embankment and secure the minimums of pressure on the face of it, the curve of the embankment should be parabolic and the new direction to be taken by the stream should be at an angle tangential to that curve.

This is done thus, by the theodolite or by mensuration on the plan, Fig. 14.

To draw a tangent to any part of a parabola, make C D = B C and join D A; D A is the tangent.

To construct a parabola, make P = 2 H and divide the sides of the triangle into any even number of equal parts, join *aa*, *bb*, *cc*, &c.; the lines will be tangents to the parabola.

The Construction of Jetties.—A jetty, if carelessly erected, undermines the opposite bank lower down the river. It should never be used at a *convex* bend of the river, only at a concave bend; it should represent the least structure that will just deflect the incoming current to the centre of the river, and no more, for the reason first stated.

Temporary deviations may be effected by 3 to 6 piles driven into the river bed and projecting in a line in a direction the angle of which shall be a tangent to the angle formed by a line representing the direction of the incoming current against the bank to be defended, and the direction of the centre of the river lower down, represented by another line, or the curve may be piled to represent a parabolic curve.

Permanent jetties are made of stone, with the usual slope given for dry stone pitching, as regards their face, of 8 inches thick at the top, increasing 3 inches per yard toward the bottom. The upstream face should be well turned into the land to prevent the current working in behind it. They are used to protect curves.

Eddies formed by Jetties.—These are most danger-

ous to cattle, and are solely the result of the angle at which the jetty projects into the river, approaching too near a right angle to the direction of the incoming current. The ultimate result is to undermine the whole jetty.

An effective protection to curves is the cultivation of water lilies and such aquatic plants, more so than generally recognised. The protection of banks by means of fascines, planting of willow slips, &c., requires no explanation; it is rarely a permanent work. Shallow, swift, minor streams, may be effectually dealt with by using 18-inch earthenware drain pipes 3 to 4 feet long, filled with concrete or stones, in place of short piles. A stake should be driven through them if used in the centre of the stream.

Sea and Tidal Defences.—These are of two kinds: ordinary precaution defences against unusually high spring tides with an on shore wind to aid them; or defences against encroachments; the larger and more extensive works consist of reclamations from the sea itself, and the construction of sea walls to protect such reclamations where the walls are exposed to the full fury of the sea.

The former class may be disposed of by observing the general principles of embankment previously explained. The embankments should be proportionally wide to the pressure they have to stand, and protected from the stripping action of the tidal current along their face by stone groins, or, if shingle of a suitable quality be at hand, by preference concrete blocks not less than 2 feet in length, by 1 foot in breadth, by 9

inches thick may be used to construct these groins or projections into the sea. These only protect five times their length, therefore short groins are to be avoided. The *battering force* of the waves must be borne in mind in constructing them.

Groins are by far the most efficient protection against also the undermining action of the sea, on earthen sea embankments especially. It will be noted that their action is to interfere with and obstruct the passage of sand and shingle along the face of the wall. That side of the groin running out to sea that is exposed to the current will ultimately be filled up level to its top with shingle, and thus by raising the level of the ground in front of that part of the defence it still further adds to its efficiency.

An earthen embankment should have a sea-face sloped at 3 to even as much as 12 to one. Its top should be not less than 7 feet above high water at full and change of the moon—*i.e.* at spring tides.

Stone defences may slope 3 to 1 to 6 to 1.

Reclamations of land and the construction of sea walls require the supervision of an experienced engineer, and a long series of observations are generally necessary before such operations can be attempted in a manner likely to repay the owner. In constructing back or low-level drains, the main drain should be excavated to such a depth that when the tidal outfall is closed, as at high tide, or if relieved by pumps during repairs, the main drain may become a reservoir. To secure this it must be *deep* enough and *wide* enough to receive a continued rainfall on the whole area drained,

without rising to a point that will block the outfall of the main land drains emptying into it. It may, if on a large scale, be wise to construct such a main drain as will admit of the use of a power dredge.

An instance of low-level drainage and its results is the Eau Brink Cut. Mr. G. Rennie, the engineer, carried out the scheme in 1825. Its object was to lead the water of the river Ouse from Eau Brink, direct across the marshes to Lynn, a distance of 2½ miles, instead of their flowing by a circuitous channel of over 5 miles in length to Lynn; the cost was, for this operation, 600,000*l*., spread over a drainage area benefited of 250,000 acres.

The effect was to greatly improve the land, so that about 150,000 acres of this area bore the cost of the Middle Level Drainage Works, or 410,000*l*.

These latter works lowered the water six feet throughout the level.

Outfalls in tidal rivers subject to æger or bore require that the maximum height of the crest of the ascending tidal wave should be estimated as the lowest outfall level. The operation of *warping* in reclamation is well known, and needs no description. The outfalls should be provided with grates to prevent salmon ascending, which cannot be tampered with. The Conservators of the Fishery District can be called upon to do this. (Refer to Fish Grates, 1873, Salmon Act, Vic. c. 36 and 37.)

CHAPTER VII.

HOUSE DRAINAGE AND DISPOSAL OF SEWAGE.

On the Modern Principles of Sewerage, with detailed Instructions for the Treatment of Old Drains and Cesspools with a view to their Removal, and Particulars for the Complete Sanitary System of a House or Group of Cottages.

THERE are two systems by which the sewage of a house may be disposed of. One by means of a properly constructed outfall drain; the other by delivery into cesspools. The latter system, though continually practised, is the most fertile source of disease, and the cause of most cases of polluted water-supply; it is in every way objectionable from an engineering and sanitary point of view, without one single feature to recommend it. To describe it would be to perpetuate the practice, therefore, suffice it to say, that where it is practised ventilation must be freely admitted into the main drain, and the cesspool itself if possible ventilated by an open grating on the top if situated at a sufficient distance from the house to ensure that it will not be a nuisance.

But where cesspools are already in use, the precautions which are necessary to minimise the danger of disease arising from the escape of their contents are as follows:—

1. They should be built of brick in hydraulic mortar or cement.

2. The foundation for the brickwork should be secure from subsidence.

3. They should be especially well ventilated, and thoroughly watertight.

4. They should be regularly emptied at stated periods, instead of being provided with overflow accommodation.

5. The storm-water drainage system should have no connection with the cesspool or its system of drains in any way whatever, neither should the waste from sinks or overflow from cisterns within the house be connected or permitted to flow into the cesspool; the waste from such sources should be turned into the storm-water system.

These precautions do not constitute a certificate of efficiency or a guarantee against disease or contamination of water-supply; the system of cesspool drainage is liable at any moment to fail, unknown to the inmates of the house, whilst if it does not fail it provides a condition of atmosphere within the cesspool and its connections that is eminently conducive to the nutrition and support of microscopic organisms, and such low classes of animal life as are inseparable from conditions of the air where fermentation and putrefaction are at work in a closed vessel.

The principle recommended for the drainage of a dwelling house, and one that cannot fail to ensure the utmost freedom from sewer gas, is as follows:—

In the first place, dealing with the type of water-

closet to be used within the house: that type known as *Underhay's patent* is the only one that experience has justified as being reliable and efficient.

The main sewer is used *solely* for sewage and stable drainage. It should be ventilated by a 4-inch iron pipe carried up the side of the house, and standing 2 feet clear above the chimney it is finally attached to; the sewer should be not less than 9 inches diameter, of glazed earthenware pipes with collars laid in clay and jointed thoroughly with well-rammed clay. When the main sewer exceeds 18 inches, earthenware pipes should be dispensed with and a properly curved brick sewer laid in hydraulic cement substituted.

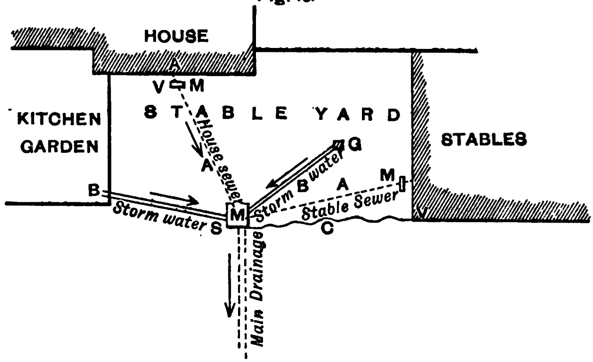
The storm-water collected over the area of the back yards, down-spouts, roofs, garden grounds, and kitchen garden, if adjacent to the house, should be carried off by a separate storm-water drain thus.

The main sewer proceeding from the house is to be carried on to a point 30 yards from the house, where it is to discharge into a man-hole, laid in cement, and the bottom made thoroughly water-tight with cement. Into this man-hole the main storm-water drain is to be turned with an S trap thus (Fig. 15).

Here A, the dotted line, represents the sewer from house, provided with a ventilating pipe, trap and inspection shaft close to the outside wall of the building. It crosses the yard obliquely to the large man-hole M, which is ventilated by the pipe indicated by a waved line to V. BB are two storm-water drains, one from the gardens, the other being the discharge of down-spouts and the water from carriage washing, &c., in the stable-

yard at the grating G. Both are trapped at the man-hole and the grates also must contain a trap. The other sewer A is the stable drain, also provided with a trap and man-hole at M.

Fig. 15.



Plan.

The effect of this arrangement is that all the sewage from both house and stables arrives *immediately* at the large man-hole M. The storm-water, cistern overflows, and stable water (of which there is usually a good deal) dilute and carry off this sewage, and in wet weather the sewer is thoroughly cleansed. No gas from one system can penetrate the other, and by occasionally turning the fire hose down one of the closets the whole sewer is freed. If a separate system for the storm-water is required at any time it can be effected economically, whilst the carrying power of the sewer may be augmented by duplicating the system. The outfall of the sewer at the extreme end should be into an

open reservoir, lined with brick and cement; the sewage may be utilised as liquid manure, or for floating the field in which it is situated. If exposed to the air there is very little nuisance; it may be planted round with coniferæ and form a small cover if necessary. If there is a considerable quantity of the sewage to be dealt with it may answer to deal with it on the A B C process as exemplified at Aylesbury. For a small village or group of cottages this process is essentially satisfactory in every sense.

In ventilating a sewer, there must be more than one pipe erected; the pipes should be of different heights, and along the line of the main sewer one in every 300 feet is ample.

In every respect the instructions for laying main drains, laid down in the chapter on Levelling and Draining and Rainfall, should be first studied. The fall for the sewer should be considerable, say not less than 1 inch in 18 feet as a minimum.

From the commencement to the completion of the work, a superintendent should be *constantly employed* supervising the work on the part of the owner. Of late years there has sprung up a class of man who calls himself a 'sanitary surveyor or engineer.' On inquiry he generally proves to be an agent for a firm who manufacture sanitary appliances, who possesses no scientific or even technical knowledge. His profession is to take advantage of every epidemic to puff his wares. It is high time, in the interest of the public generally, that a standard Government examination should be held by a board of members of the Institu-

tion of Civil Engineers to grant certificates of competency to engineers and surveyors, which the public may ask to see before committing themselves to the tender care of the 'sanitary inspector.' A few more words may be said on this point in regard to the *alleged* properties of filters.

The most economical and satisfactory plan is to call in a competent engineer who possesses the necessary diplomas to advise as to the general system most suited for the purpose, and let his report and plans, with their sections to show the rate of fall, be entrusted to the agent or clerk of the works.

Many agents are fully competent to execute sewage works, but they have not the time to devote to it, and in most cases it will be wise to allow the engineer to appoint a superintendent to relieve the agent of the necessity of constant attendance.

The principal sanitary points to be observed to secure good drainage are these:—

Natural streams should not be arched over and then converted into main sewers.

The greatest attention and care is to be exercised in making joints thoroughly gas and watertight.

Closets should always if possible be built against an outside wall; they should have an ante-room to them well ventilated to the outside air, and thus cut them off from the internal communications of the house. Down-spouts to carry off the water from the roof should always discharge into a trapped catch basin with a space of 6 inches from the end of the spout to the brickwork or grate forming the basin. Then they can

always be tested to see if they act, and do not connect with any drain. The laying of drains under the house is objectionable, but if absolutely necessary, they should be laid in concrete.

Traps should contain a column of water of not less than 8 inches in height.

All brickwork to be laid in Portland or hydraulic cement not less than 1 to 3 of sand well washed. Before filling in the storm-water and other drains, their efficiency should be tested with water, and the gas traps tested by blowing sulphur fumes into the main sewer; no smell should be perceptible at any storm-water grate or in the closets. Oil of peppermint may be substituted. In this case the oil is diluted and the whole poured down a storm-water grate. The tops or flags closing the man-holes should be cemented down, and 8 to 12 inches of charcoal the size of a walnut spread over them, before covering over with soil.

The calculation of the size of the pipes, taking 6 inches as the minimum for sewer pipes and branches, will be based on the chapters devoted to Rainfall and Drainage.

The soil pipe of the closets should be carried to the roof and a ventilator attached. It should be of lead, not less than 4 to 6 inches diameter; the curves to be all parabolic. The soil pipe should be well *supported* as well as secured, to prevent it drawing out by its own weight, every 10 feet.

A free and sufficient supply of water to be allowed to flush each closet, not less than 2 gallons each time the closet is used.

Re-draining.—A few special precautions are to be taken in re-draining a house previously drained on the cesspool system. In following up the main drain, all earth that is the slightest discoloured to be thrown out and carted right away; every branch joining or crossing the main drain is to be followed up, dug out, and similarly treated. Cesspools to be emptied, and their bottoms dug out to the clean soil, well limed and filled in with clean earth, but by preference concrete. (Care to be taken that when empty they do not collapse inwards and bury the men engaged.) After first opening cesspools it is advisable to stir their contents and leave them for a few hours to give off their putrescent gases, &c., before commencing to empty them.[1] The excavations, after the pipes are taken out, are to be filled in with clean earth carted in different carts to those that remove that excavated. The bricks lining the cesspools are not to be used for any building purpose at any future time; they should be broken up for use on the roads of the estate, or in gateways on the farms.

It is always to be recognised in drainage operations where sewage is concerned that a very small leakage from a drain may pollute a whole water-supply and water-bearing strata. The writer has frequently found wells regain their purity after cesspools and their defective connections had been removed, but two or three years must first elapse, and the water should not be drunk without a chemical analysis being first obtained of it. Re-drainage is generally better than sinking for a pure supply of water in such cases.

[1] See tables of brick sewers and earth work in Appendix.

Messrs. Walter Macfarlane & Co., Glasgow, have in stock every description of iron-trapped grate and sanitary fittings, and make a speciality of such work. The locality of the work will of course govern the contractor's price; the better way is for the engineer to order all such traps, &c., and allow the contractor upon them; the type most suited to the work can then be procured; the landed proprietor is again cautioned against patent ventilating cowls, &c., and recommended to consult an engineer of recognised ability.

The plan of the drains should be of a scale of 1 inch = 10 feet; the sewers coloured red, and storm-water drains blue; every trap, man-hole, siphon, ventilator, down-spout, grate, or other connection should be shown; the rate of fall should be marked in. The tenant, if any, should also have a copy of the plan. Additions and alterations should be marked up as made, with date of every alteration clearly indicated on the plan.

The A B C Process of treating Sewage.

Experience at Aylesbury and Leeds has shown that this simple and effective process of purification by chemical precipitation is eminently adapted for villages and groups of cottages. It is in those localities that fever is bred, and spread by want of common precautions at the Board school. Can anything be more disgusting than the ordinary sanitary provisions of a group of cottages; and what so unnecessary? In this process after purification in the tanks the effluent water is discharged into the nearest stream, being pure within

the requirements of the Rivers Pollution Act. For an annual payment of from 1*s.* to 1*s.* 3*d.* per head of population the sewage may thus be satisfactorily disposed of. At Leeds thirteen million gallons of sewage are thus treated per day, the cost of purification being per million gallons, 1*l.* 6*s.* 9¼*d.* The effluent analysis is as follows:—

GRAINS PER GALLON.

		Standard fixed by the Rivers Pollution Act	Standard fixed by the Thames Conservancy
In solution. Actual ammonia	1·20	No standard	No standard
Organic nitrogen or albuminoid ammonia	0·14	0·21	0·75
Total nitrogen as ammonia	1·34	No standard	No standard
Chloride of sodium . . .	11·79	,,	,,
Mineral matter . . .	54·54	,,	,,
Organic ,, ...	4·59	,,	,,
Total solids in suspension ·	59·13	,,	100·00
Organic carbon	0·92	1·40	2·00
Mineral matter in suspension .	0·22	2·10	No standard
Organic ,, ,, .	0·32	0·70	
Total	·54	2·80	5·00

The products of the process are in the form of an artificial manure which takes less than 2*l.* to produce by the purifying process, and which experience shows has an agricultural value of 3*l.* 10*s.* per ton. Thus, by experiments conducted at Crossness, its effect is realised.

GOLDEN DROP WHEAT.

		Yield in bushels per acre
Native guano 15 cwts. per acre,	6 lbs. 4½ ozs.	56·2
,, ,, 10 ,, ,,	6 ,, 1½ ,,	54·6
None . . . . . ,,	2 ,, 14 ,,	25·7

BLACK TARTARY OATS.

		Yield in bushels per acre
Native guano 15 cwts. per acre,	6 lbs. 8 ozs,	58·3
No guano	3 „ 14 „	34·7

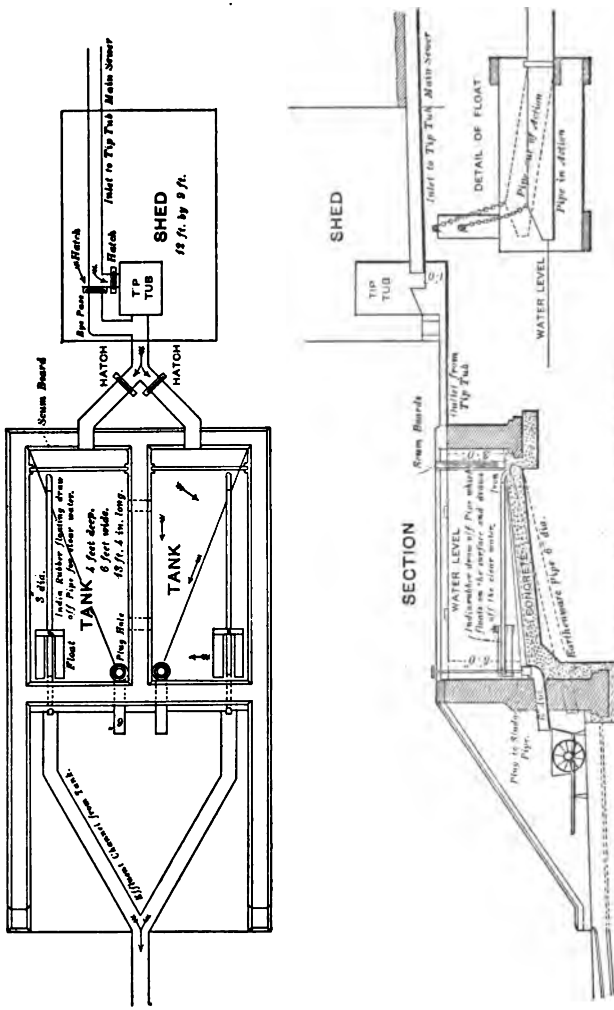
The yield is given on patches 9 yards square and per acre at that rate of yield.

The tank room should be sufficient to accommodate 15 hours' flow of sewage.

In the case of private houses such as schools, or large public buildings such as are maintained in every county for lunatics, this process is doubly useful, as, whilst dealing with the sewage, it also provides an efficient manure for neighbouring farms supplying their produce. In this case or in that of a group of cottages the following plan should be adopted to save pumping by a gravitation system of flow. Each tank should contain 24 hours' flow of sewage, and the two tanks should be worked alternately. The sewage should be sold as removed from the tanks; it probably would not pay to dry it. The chemicals which are added to the sewage during treatment in the tanks renders this sludge quite inodorous, so no nuisance is caused and hardly any labour required. Wellington College is an instance of the system on a small scale; Aylesbury is provided with a considerably larger system; in Leeds is an instance of its application on a very large scale. The works of the Company are at Aylesbury, so that it can there be seen in operation. The treatment of the Leeds sewage is an excessively difficult question on account of the numerous dye works and manufacturers' waste products that enter the sewers; but the cost has

only averaged about 1*l.* 17*s.* per million gallons purified, for the necessary chemicals such as alum, charcoal, and the other ingredients that constitute the treatment of the sewage. In my opinion it is without question an effective way of dealing with sewage, and I can conceive no place in the world that would benefit from its process so much as Australia, where drainage and sanitary matters generally are very primitive, and where the products might be so valuable on the poor sandy soils met with there. In England its application to those hot-beds of illness in the shape of groups of cottages should engage the attention of the landowner; and the well-known structure, offensive both to eye and nose, that is always to be seen in a cottage garden should be improved out of sight. The present arrangement referred to is a disgrace to the landlord and tenant alike, and a reflection on the responsible sanitary authorities. How is it possible for non-polluted water to be got with such an arrangement? When the holes dug, over which these structures stand, are full, a fresh site is often chosen, the ultimate result being that the garden becomes one mass of cesspools, the existence of which is unknown. So much is said in the present day about '*sanitation,*' and such nonsense talked about the ideal labourer who is going to pay 2*l.* for a water filter, which represents itself to his mind as some 500 glasses of beer the less in money value, that the writer may be excused for saying that the present cottage sanitary arrangements are antagonistic to all social improvements and temperance; and that before you can persuade a working man of the efficacy of pure

FIG. 16.



NOTE. This Plan is not drawn to Scale.

water you must be in a position to produce the article, and before self-respect is expounded to him, he should have the means of exercising it. But improved drainage and thereby pure water costs money. Let the landlord, then, execute the work and charge his 1*s*. 3*d*. a head on the rent, or if in a village of some extent let a local Gas and Drainage Co. be formed. The present injudicious agitation against the owners of cottages in the country *effects nothing*, but exasperates the owners, who are blamed *en masse* for not laying out capital to improve the condition of a class who cannot afford, or at all events do not pay an increased rate for an increased benefit, a commercial maxim too apt to be overlooked by those illusionists who use the meetings of congresses and conferences to base an attack upon all owners of cottages and estates, because they do not appear too eager to pay heavily in depressed times for what after all is but the illusionist's hobby. It is one thing to propose improvements and distinctly another to have to pay for them. Cottages in England have greatly improved in the last thirty years; a *system* of drainage in place of what exists is required. The A B C process is in effect the very system for the purpose; the cost being 1*s*. 3*d*. per head per annum, the problem is set at rest by the introduction of an Act empowering a landlord to carry out the work and rate those benefited. Where the hitch lies in cottage improvements is that experience has taught landowners it does not pay. But what we do most strongly condemn is the ever-increasing practice of men with neither technical, special, or indeed any knowledge of

the subject, making abuse of landowners a step-ladder to notoriety. It is my experience that disastrous results have followed such idle talk, and clergymen of parishes cannot learn too soon that the *land agent's office* and not the *platform* is the proper place to urge improvements to raise the social condition of the cottagers in his parish ; and that whilst sanitary knowledge and the wants of everyone have greatly increased, the landowner's income and security for it has greatly diminished, and that in considering the interest of one class to abuse another can advance the interests of neither. Calm and dispassionate discussion with the agent is the more dignified way of dealing with these matters and the most likely to achieve the end. The cost and means are described here.

CHAPTER VIII.

WATER SUPPLY AND FILTRATION.

On Water Supply, its Purity, and Tests for the same, and the Principles of Filtration, with Reference Tables of Consumption and General Details of Water Supply Service.

THIS is one of the most important questions. Modern science has revealed causes of impurity hitherto neglected, and the extensive engineering works that have of late years been executed have been the means of deciding many points in the filtration of water. The actual supply of water to a large house may be by three methods: artesian supply, by pumping and gravitation, and lastly by wells. The former method is entirely dependent on the geological nature of the ground; the two latter systems may not be as convenient as the former; but, by a careful choice of site and depth, the quality and quantity of water may be secured as effectually as by the artesian supply. Failing these sources of natural supply, river water may be utilised.

Artesian borings[1] may be projected with prospects of success when the following geological conditions exist: if the water-bearing strata has its gathering ground at a considerable elevation above the spot where the

[1] See section of strata of London clay basin, Fig. 22.

boring is to be commenced, and is covered by an impervious stratum, the water, on piercing this layer, will rise up to a height nearly level with that of the gathering ground. The preliminary survey in such a case should be entrusted to the care of an experienced engineer. The system by pumping and gravitation is the most common. In this case, a suitable supply of water having been found, it is pumped by hand, steam, or hydraulic power into a tank or water tower, constructed on some rising ground some 100 feet above the roof of the house to be supplied. The pipe that conducts the flow of water from the well to the tank is termed the '*rising main*' in contradistinction to the '*service main*' or supply from the tank to the house.

The mains should be of such a diameter as shall provide sufficient flow, and leave a margin for rusting up or furring inside.

CAST-IRON WATER PIPES.

Bore in Inches	Thickness of Metal	Depth of Socket	Thickness of Socket	Packing Space	Weight per 9 ft. Length			Weight of Lead Joint
	in.	in.	in.	in.	cwt.	qrs.	lbs.	lbs.
3	$\frac{5}{16}$	3	$\frac{5}{8}$	$\frac{1}{4}$	0	3	24	2·4
4	$\frac{5}{16}$	3	$\frac{5}{8}$	$\frac{1}{4}$	1	1	14	3·6
5	$\frac{3}{8}$	$3\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	1	2	16	6·0
6	$\frac{3}{8}$	$3\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	2	0	0	8·2
7	$\frac{3}{8}$	$3\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	2	1	4	8·7
8	$\frac{7}{16}$	$3\frac{3}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	3	0	4	9·9
9	$\frac{7}{16}$	4	$\frac{3}{4}$	$\frac{3}{8}$	3	1	19	13·9
10	$\frac{1}{2}$	4	$\frac{3}{4}$	$\frac{3}{8}$	4	1	16	14·9
11	$\frac{1}{2}$	4	$\frac{3}{4}$	$\frac{3}{8}$	4	2	22	15·9
12	$\frac{9}{16}$	4	$\frac{7}{8}$	$\frac{3}{8}$	5	2	24	17·2
14	$\frac{5}{8}$	4	$\frac{7}{8}$	$\frac{3}{8}$	7	2	24	20·8

NOTE.—The 9-foot length is taken from the end of one pipe to the end of the next when laid.

The preceding table is applicable to cast-iron water pipes proved to 400 feet head of water, to work at 200 feet water pressure.

The weight of such cast-iron pipes is got thus:—

D = outside diameter of pipe in inches.
E = inside " " "
W = weight per yard of pipe in lbs.

$$W = 7{\cdot}35 \times D^2 - E^2$$

Two flanges = $\frac{1}{3}$W in weight.

The tank may be buried in the hill and arched over, or it may, if extra height is required, be placed at the top of a water tower.

In the former case, more reservoir room is generally obtained; four days supply without pumping should always be provided for.

Hawksley's formula for the delivery of water in pipes in gallons per hour is to be applied to decide the proportions of the two mains, thus:—

G = number of gallons in the house to be delivered.
L = length of main in yards.
H = head of water in feet.
D = diameter of main to be employed.

$$D = \frac{1}{15}\sqrt[5]{\frac{G^2L}{H}} \qquad G = \sqrt{\frac{(15\,D)^5\,H}{L}}$$

The size of the storage reservoir will be that figure or shape that is most suited to the ground, whose cubic contents are four times the quantity consumed daily in the house and stables.

Its construction should be of brick laid in cement. If an embanked reservoir, these points must be ob-

served in forming the embankment. It is to be made of clay in layers, well rammed, and should contain a '*puddle wall*' or watertight partition of a thickness of one-third the total height, at the base. The slopes are to be turfed, but no trees or shrubs planted anywhere near or on them.

The supply or service main should have a sluice valve set in a frost proof brick man-hole at its entrance to the reservoir, and again, one just outside the house itself, so as to cut off supply for repairs or accident, such as leakage.

The service main will supply the *water supply of the house for drinking purposes* from one tank provided with spongy iron filters as described later; *the hydrants and closet service* will be from a different tank, and unfiltered. Pressure gauges are to be attached to the drinking water supply and hydrants to show that all is in order.

The course recommended is for the agent to make a calculation of the total number of gallons required daily, with a large margin in case of fire; levels should then be taken and shown on a $\frac{1}{25}$ Ordnance sheet. The sinking the wells and providing of machinery is essentially a thing requiring great experience, and no rule can be laid down here to guide, every case having to be treated on its merits. Messrs. Easton and Anderson, of Erith and 3 Whitehall Place, have executed many contracts of this nature for the writer, and for such work as water supply or hot-water service, the experience they have gained in country mansions is a sufficient recommendation.

Well-sinking is an operation best entrusted to local contractors. Surface water must not be allowed to filter into the well. Especially is this liable to occur at cottages, if not seen to and provided against by lining in cement or puddling. The mouths of draw wells should be closed.

Causes of Pollution of Water Supply, and their Removal.—We have seen in the previous chapter that, except there be good drainage first, there cannot be a safe water supply. A polluted supply may be purified by filtration, but here again the filter may and does frequently fail.

The causes of pollution to the source of a well are the presence of old cesspools, or defective drainage; surface water entering the well by percolation; wooden fixtures left rotting in the well or old wooden buckets left to rot in the water, and lastly organic life in the form of bacteria and hydatids. The latter is more confined to dirty tanks or ponds accessible to sheep.

All drinking water should be filtered for use. Carbon filters, in the writer's opinion, are useless. In support of this, the writer may instance a case of severe outbreak of diphtheria amongst the staff on the construction of a line of railway on which he was employed, where carbon filters were in use as the *only* possible means of water supply. They do not remove albumenoid ammonia, neither is it removed by boiling. The quality of the carbon supplied in many cases is inferior, whilst its efficacy is greatly exaggerated and calculated to mislead in every way. Two classes of danger must be removed from drinking water—the one, excrementary

products, the other the low organisms that exist in them. A class of the latter, called entomostracæ, may be kept for several months in a weak solution of excrementitious matter. Is it to be maintained that the carbon effectually removes such minute organisms; can it be maintained that it even removes albumenoid ammonia? The writer's experience is distinctly to the contrary. Here is a simple test for the efficacy of water filters as regards such organisms. It is known as Koch's Gelatine Test. $2\frac{1}{2}$ per cent. of pure gelatine is to be heated, and when at a considerable temperature it is to be added to the *filtered* water to be examined. Firstly, the water appears as a gelatinous thick fluid at rest. Kept under observation for a day or two, in an hermetically sealed glass flask, organic centres will develop which do not sink to the bottom. Each centre becomes a sphere of organic activity. In some cases the sphere may appear as an ovoid vesicle containing liquid; in another day or two, a whitish grey deposit takes place in the spheres. This is to be removed by a suction tube (care being taken not to get any in the mouth) and examined under a microscope; it will be found to be a living mass of bacteria, moving in a putrescent fluid.

No chemical analysis will determine absolutely the existence of such organic life.

The water, after filtration, must not be exposed to the infective influence of the atmosphere. Suffice it to quote the report of the Statistical Sanitary Committee of the Prussian Army, 1874 to 1878. Speaking of Bischoff's spongy iron system, it says: 'The improve-

ment of the water is unquestionably greater than by any other known system.'

For house supply, the spongy iron system is in every way most suited to the purpose, on account of the freedom from cleansing; the material requiring removal after periods of 1 to 3 years. For farm and cottage filters it is very useful. It is an undoubted fact that spongy iron is most destructive to low organisms. Mr. W. Anderson's valuable paper on the subject (vol. lxxii. Session 1882–83, part ii., 'Proceedings of the Institution of Civil Engineers'), giving his experience in the Antwerp waterworks, confirms this. It may be safely concluded that it is the most fatal form of filtration to bacteria.

The power or means to fill the reservoir may be estimated from the tables given for steam and hydraulic engines. Gas and hot air may be employed in such instances where it is already in use.

The estimated power required to raise water from deep wells must be so proportioned as to leave a considerable margin for ultimate extension of the supply.

POWER TABLE FOR DEEP WELLS.

		Maximum Depth from which this Quantity can be raised by each Unit of Power			
Diameter of Pump-barrel in Inches	Gallons of Water raised per Hour	One Man Turning a Crank	One Donkey Working a Gin	One Horse Working a Gin	One Horse-power Steam Engine
2	225	80	160	560	880
2½	360	50	100	350	550
3	520	35	70	245	385
3½	700	25	50	175	275
4	900	20	40	140	220

The depths are given in feet. The type of pump is the double-action lift and force pump.

Where a fall of water is obtainable of some volume, a turbine (or an hydraulic ram) is the best means of driving the pumps, which should then consist of a set of horizontal three-throw pumps. The ram raises water direct without pumps. It should be well protected from the frost. Turbines are made for both high and low pressure, and to work flooded.

The power of the hydraulic ram is thus calculated.

Q = quantity in cubic feet per minute of water used.
H = head of water in feet.
P = effective horse-power.

$$Q = \frac{881\ P}{H}$$

$$P = \cdot 00113\ Q\ H.$$

In practical effect $\frac{1}{7}$th of the water may be raised to about four times the height of the supply, or head; $\frac{1}{14}$th eight times, and $\frac{1}{28}$th sixteen times, and so on.

The effective horse-power for different motors with water is:—

Theoretical power being supposed . .	= 1·00
Undershot water-wheel	= ·35
Poncelet's „	= ·60
Breast wheel	= ·55
High „	= ·60
Overshot wheel	= ·68
Turbine	= ·70
Hydraulic ram raising water . . .	= ·60
Water pressure engine	= ·80

In the following chapter a table is given of nominal

horse-power for one foot fall for the three types of water-wheel and turbine.

The operation therefore of water-supply, to be carried out effectually, consists in first estimating the quantity required per 24 hours; the height to which it is to be forced must next be decided by level; the power to be used is then got. On these data a well may be sunk, but that part of the system is best entrusted to the engineer. To describe the process or to lay down rules would be impossible here.

The *hardness of water*, if excessive, is best removed by Dr. Clark's method.

This is due to an excess of bicarbonate of lime in the water. It is easily removed by adding to the water an amount of lime equal to that already present as bicarbonate of lime. The added lime combines with one half of the carbonic acid, the result being that it becomes chalk itself and reduces the bicarbonate to chalk also. Each gallon of water weighs 70,000 grains, so that in speaking of the *degree of hardness* of water, it means the number of grains that are formed as chalk in a gallon of water. Water of 5° to 7° of hardness is soft, 12° to 13° would be very hard.

In pumping with a horse and gin, sometimes the machinery overruns the horse if he stops suddenly. To prevent accident occurring from this, Messrs. Nicholson, of Newark, have a very excellent arrangement of safety gear that cannot get out of adjustment. Some arrangement of this sort should always be attached to a gin.

Filtration for impurities, as previously shown, is best effected by the spongy iron process.

A very useful form of pump is that constructed by Legrand and Sutcliffe, of London, and known as the 'Abyssinian tube well pump.'[1] Where existing wells near farm-houses are polluted, or to supply a group of cottages or stock, these pumps should be tried before sinking a well, if the water-bearing strata are fairly accessible at no great depth. Small 3-gallon spongy iron filters are best suited for cottages. I have not found it to be, as urged, that cottage tenants will not use them; on the contrary, they have been very glad to have them. It is their first cost that they cannot pay. Sick clubs might well see to this point, and provide filters to their members at half cost.

[1] See note in Appendix, 'Screw tube pumps.'

CHAPTER IX.

HYDRAULIC POWER—SLUICES, TANKS, AND PIPES.

On Water Power, Hydrants, Hose, Tanks and Pipes—Soft Water Reservoirs and Hydraulic Lifts, with Hydraulic Pressure Tables.

THE hydraulic power of a stream is calculated by estimating the weight in pounds of the number of cubic feet supply of the stream per minute divided by 33,000. The result is called the nominal horse-power of the water. The 'duty' performed by the machine actuated is the effective horse-power. The latter subtracted from the former is the amount of power lost and absorbed by friction. The duty of a properly erected water-wheel is about 60 per cent. The accompanying table shows, from the experience gained from

TABLE OF WATER-WHEELS.

Fall	Cubic Feet required	Diameter	Breadth	Depth of Bucket	Speed of Periphery per Minute	H.-P.	Breadth and Pitch of Teeth in Inches
		ft. in.	ft. in.	ft. in.			
—	—	65 0	6 0	1 0	—	—	$10 \times 3\frac{1}{2}$
26·6	—	28 0	13 0	1 10	—	—	—
16·6	2,760	20 0	17 0	1 8	229·2	60	$12 \times 3\frac{1}{4}$

water-wheels constructed by the late Sir W. Fairbairn, C.E., the proportions of water-wheels with some results obtained.

Power derived from water-wheels is very frequently applied to pumping; for driving machinery it is exceptionally useful, on account of steadiness.

To obtain the hydraulic power of the stream, if very small in volume, or if it is a mountain stream which is liable to come out after rain, and in a dry summer go in to nothing hardly, it is desirable to form an accumulating reservoir at one or two places, to collect the flood water and store it; by this means a very small stream may be impounded to yield a continuous supply of power to drive an hydraulic engine or turbine. The power, of course, must be calculated from the height of the water in the lowest accumulating tank, not from the head of water given by the stream. The necessary storage capacity can be got by studying the rainfall and by gauging the stream; the longest consecutive drought being the point to ascertain; the average weekly quantity of water required for power must then be got, and the two compared.

The following table will give the nominal horse-power for one foot of fall for different discharges. To use it, add together the number from the column applicable to the case opposite the several numbers making up the run or volume of the stream. Multiply their sums by the several feet of fall, the answer is the effective horse-power of the mill :—

TABLE OF NOMINAL HORSE-POWER PER 1 FOOT FALL OF WATER.

		Effective Horse-power			
Discharge of Stream per Minute	Nominal H.-P.	Undershot Wheel	Breast Wheel	Overshot Wheel	Turbine
5	·0095	·0033	·0052	·00615	·0071
10	·019	·0066	·006	·012	·0142
15	·028	·0099	·015	·018	·021
20	·038	·013	·020	·024	·028
25	·048	·016	·026	·031	·035
30	·057	·020	·031	·037	·042
35	·066	·023	·036	·043	·050
40	·076	·026	·041	·049	·057
45	·085	·030	·046	·055	·064
50	·095	·033	·052	·061	·071
55	·104	·036	·057	·068	·078
60	·114	·040	·062	·074	·085
65	·124	·043	·067	·080	·092
70	·133	·046	·072	·086	·099
75	·142	·050	·078	·092	·106
80	·152	·053	·083	·098	·113
85	·161	·056	·088	·104	·121
90	·171	·059	·093	·111	·128
95	·180	·063	·098	·117	·135
100	·190	·066	·104	·123	·142
200	·380	·130	·208	·246	·284
300	·570	·200	·312	·369	·426
400	·760	·260	·416	·492	·568
500	·950	·330	·520	·615	·710
600	1·140	·400	·624	·738	·852
700	1·320	·460	·728	·861	·994
800	1·520	·530	·832	·984	1·136
900	1·710	·590	·936	1·017	1·278
1,000	1·900	·660	1·040	1·230	1·420

An ordinary mill will grind 1 bushel to 1·2 bushels per horse-power per hour. For connecting hydraulic pressure gauges, a table of pressures is also given. It may be applied to steam engine gauges also. It will be found necessary also in the construction of tanks,

&c., and in the calculation of pressure on hydrants and pipes.

MERCURY AND WATER COLUMN PRESSURE TABLE.

Mercury Column	Water Column	Pressure per Sq. In.	Pressure per Sq. Ft.	Mercury Column	Water Column	Pressure per Sq. In.	Pressure per Sq. Ft.
Inches	Feet			Inches	Feet		
·1	·113	·049	7·07	28·56	32·39	14·000	2,016
·2	·226	·098	14·14	29·00	32·88	14·21	2,050
·3	·339	·147	21·21	30·00	33·92	14·70	2,121
·4	·452	·196	28·28	30·60	34·71	15·00	2,160
·5	·565	·245	35·35	31·00	35·05	15·19	2,191
·6	·678	·294	42·42	32·00	36·18	15·68	2,262
·7	·791	·343	49·49	32·64	37·02	16·0	2,304
·8	·904	·392	56·56	33·00	37·31	16·17	2,333
·9	1·017	·441	63·63	34·00	38·44	16·68	2,404
1·0	1·1306	·490	70·70	34·68	39·33	17·00	2,448
2·0	2·260	·980	141	35·00	39·57	17·15	2,474
2·04	2·314	1·00	144	36·00	40·70	17·64	2,545
2·08	3·39	1·47	212	36·72	41·62	18·00	2,592
3·0	4·52	1·96	282	37·00	41·83	18·13	2,616
4·0	4·63	2·00	288	38·00	42·96	18·62	2,686
4·08	5·65	2·45	353	38·76	43·96	19·00	2,736
5·0	6·78	2·94	424	39·00	44·09	19·11	2,757
6·12	6·94	3·00	432	40·00	45·22	19·60	2,828
7·0	7·91	3·43	495	40·80	46·28	20·00	2,880
8·0	9·04	3·92	565	42·84	48·59	21·00	3,024
8·16	9·25	4·00	576	44·88	50·90	22·00	3,168
9	10·17	4·41	636	45·00	50·87	22·05	3,181
10	11·306	4·90	707	46·92	53·21	23·00	3,312
10·20	11·57	5·00	720	48·96	55·52	24·00	3,456
11	12·43	5·39	790	50·00	56·53	24·50	3,535
12	13·56	5·88	848	51·00	57·83	25·00	3,600
12·24	13·88	6·00	864	60·00	67·83	29·40	4,242
13	14·69	6·37	919	70·00	79·14	34·30	4,949
14	15·83	6·87	990	80·00	90·44	39·20	5,656
14·28	16·20	7·00	1,008	90·00	101·75	44·10	6,363
15	16·96	7·36	1,060	100·00	113·06	49·00	7,070
16	18·09	7·85	1,130	110	124·34	53·90	7,777
16·32	18·51	8·00	1,152	120	135·67	58·80	8,484
17	19·22	8·34	1,202	130	146·70	63·70	9,194
18	20·35	8·83	1,272	140·00	158	68·70	9,898
18·36	20·82	9·00	1,296	150·5	170	73·78	10,625
19	21·48	9·32	1,343	159·3	180	78·12	11,249
20	22·61	9·81	1,414	168·2	190	82·46	11,874

Mercury Column	Water Column	Pressure per Sq. In.	Pressure per Sq. Ft.	Mercury Column	Water Column	Pressure per Sq. In.	Pressure per Sq. Ft.
Inches	Feet			Inches	Feet		
20·40	23·14	10·00	1,440	177·00	200	86·80	12,499
21	23·74	10·29	1,484	194·7	220	95·48	13,749
22	24·87	10·78	1,555	212·3	240	104·16	14,999
22·44	25·45	11·00	1,584	230·1	250	108·50	15,624
23·0	26·00	11·37	1,626	247·8	260	112·80	16,243
24	27·13	11·76	1,696	265·3	280	121·50	17,496
24·48	27·76	12·06	1,728	283·06	300	130·20	18,748
25·00	28·26	12·25	1,767	—	320	138·80	19,987
26	29·39	12·74	1,838	—	350	151·90	21,873
26·52	30·08	13·00	1,872	—	400	173·60	24,998
27	30·52	13·23	1,909	—	450	195·30	28,123
28	31·65	13·72	1,979	—	500	217·00	31,248

Hydrants for fire extinction. (For Hose and its Care, *see* Steam Fire Engines.) These are openings at stated intervals along the fire main outside the house at which a length of fire hose may be readily attached. They should be placed at a distance from the building of not less than 20 feet. The hydrant supply or fire main should completely encircle the house and stables, and its diameter should be such as to allow three jets to be used from it simultaneously. Messrs. Shand and Mason have constructed almost every description of arrangements, both of stand pipe and pillar hydrant.[1] Frost is to be guarded against. It is most essential, and has been amply proved by experience, that *force* is everything in extinction of fires; therefore, except an exceptionally large head of 100 to 150 feet can be obtained by water towers, or tanks on rising ground,

[1] To prevent rusting use the Rust Compound sold by Bradley and Bourdas, Chemists, Pont Street, Belgrave Square, London, W., as directed, for all such work.

or a combination of the two, hydrants are not a sufficient protection against fire in a country house. If an engine, steam or manual, be kept, care should be taken to adopt a uniform gauge of union for both engine and hydrant hose. The L.F.E. (London Fire Engines) hose is in 40 feet lengths, 2½-inch waterway, leather and copper rivetted, costing about 7*l.* 10*s.* a length. With proper care 30 years is the fair life of such hose. Hydrants must be allowed to flow freely at least four times a year, on account of the main becoming rusted up. A vertical rising fire main within the building, with branch mains to wings, and fire stations on every floor is advisable. A stop-cock should be provided at each branch to cut off the supply from any wing in case of leakage, and the same at the entrance of the main itself to the building. A pressure gauge should be attached in the wings and the main. The duty of some responsible person should be to read and note the gauges at sundown every day, lest the mains should be out of working order. The wing and other inside connections must be run off periodically. This is best done by attaching a length of hose and delivering out of the nearest window, ceasing when the water runs clean. Leather hose will stand 150 to 250 lbs. pressure.

Tanks and Pipes.—Some observations may be made here with regard to the above. Iron tanks are in every way preferable to wooden tanks. Wooden tanks are not suited for water-supply when lined with lead. For small tanks galvanized iron is preferable. The weight of all forms of tanks should be well dis-

tributed on the supports. It may easily be obtained by the following :—

1 cubic foot of water			= 6·24 gallons.
1 ,,	,,		weighs 62·645 lbs. or ·557 cwt., or ·028 of a ton.
1 ,, inch	,,	,,	·03612 lbs.
1 gallon	,,	,,	10 lbs. or measures ·16 feet cube.
1 cwt. of water			= 1·8 cubic feet = 11·2 gallons.
1 ton ,,			= 35·9 cubic feet = 224 gallons.

Hydraulic General Formula.

P = pressure in lbs. per sq. inch.
H = head of water in feet.
V = theoretical velocity in feet per second.
G = force of gravity.

then

$$P = H \times \cdot 4335.$$
$$H = P \times 2\cdot 317.$$
$$\text{Pressure per sq. ft.} = H\ 62\cdot 4.$$
$$G = 32\cdot 2. \quad 2\,G = 64\cdot 4. \quad \sqrt{29} = 8\cdot 025.$$
$$V = \sqrt{2GH} = 8\cdot 025\sqrt{H}.$$
$$H = \frac{V^2}{29} = \cdot 0155^2\,\frac{1}{29} = \cdot 0155.$$

Sea Water.

1 cubic foot weighs 64·11 lbs.
1 ,, equals 1·027 of fresh water in weight.

Rainfall.

Inches of rain × 2323200 = cubic feet per sq. mile.
" " × $14\frac{1}{2}$ = millions of gallons per sq. mile.
" " × 3630 = cubic feet per acre.

Large iron tanks must be securely stayed inside, and the rivets and stays examined before painting.

If lead lining is used with wooden tanks, care must be taken with regard to weight that that of the lead is taken into consideration. In this case the wooden tanks must be strengthened with wooden partitions. Tanks for water-supply should be exposed to a fresh current of air and daylight. They should be easily accessible for inspection and cleaning, and in *no way connected with the water-supply of closets.* A test for lead in water is to pour two drops of hydrochloric acid into a little of it. A white precipitate will fall, which will become black if a few drops of sulphuretted hydrogen solution be added; the precipitate is first a chloride then a sulphide of lead. A reverse of this chemical reaction is a reliable test for sulphuretted hydrogen gas, or sewer gas. A strip of white blotting paper is soaked in solution of lead acetate; it is suspended in the suspected drain pipe or closet. If it becomes blackened, it shows the presence of the gas by the deposition of the black sulphide of lead. Rain-water tanks occasionally become offensive. It is always desirable to throw in a few shovelfuls of animal charcoal to act as a deodoriser.

The flow and return to hot water circulating tanks

for hot water apparatus is liable to become choked or reduced in waterway if only hard water be used; to reduce this, one or two roof spouts may deliver into the hot water feed tank.

Pipes.—The flow through pipes in gallons and the diameter required for a certain flow is calculated from Hawksley's formula, thus:—

G = gallons delivered per hour.
L = length of pipe in yards.
D = diameter „ inches.

$$D = \frac{1}{15}\sqrt[5]{\frac{G^2L}{}}. \qquad G = \frac{\sqrt{(15D)^5H}}{L}.$$

By Neville's general hydraulic formula for cylin drical pipes the same results may be obtained. (*Vide* 'Molesworth's Engineering Formulæ,' page 184.)

To estimate tankage room and service pipes required, provide as a minimum

For each	person . . .	25	gallons per day.
„	horse (in stables) .	15	„
„	closet . . .	2	„
„	bath-room . .	50	„
„	bath used . .	4	„
„	waste . . .	15	„
„	carriage (stables) .	25	„
„	„ 2 wheeled „ .	10	„

The service pipes within the house should be protected from frost and provided with shut-off cocks in case of leakage. They should be numbered, and a corresponding plan kept of them for reference, other-

wise the local plumber will probably connect a new closet water service on to the water-supply, or some such mistake will occur; these will utterly negative the results anticipated from good drainage.

Reservoirs should hold 3 to 4 days' supply. The size of soft water reservoirs may be thus arrived at. The fall of rain over roofs in England may be taken at not less than 18 inches per annum. The area of collecting roofs is to be added together and the discharge calculated by the tables in the chapter on Rainfall; the reservoirs should hold twice to three times the amount. Details of pipes are given as regards bore and weight in the chapter devoted to Water-supply.

Hydraulic, Goods, and Passenger Lifts.—It should be clearly understood that except a lift be a direct acting ram lift it is unsafe for people to use. Geared or hydraulic-mechanical lifts are only safe for luggage. The fire-main indoors may form the supply for such lifts. They act on the well-known principle of the hydraulic press. The cage should always be roofed with a proof plate of boiler iron. Of safety appliances to check the descent of the cage in the event of a broken chain, &c., I can only say they are one and all absolutely useless both in lifts and in the more serious case of coal mines. The overflow and exhaust from hydraulic lifts may be used to flush the sewer in dry weather. It must be most carefully trapped inside and out as well.

PART II.

ON MATERIALS USED IN REPAIRS AND CONSTRUCTION, WITH INSTRUCTIONS FOR UTILISING LIMESTONE AND CLAYS.

CHAPTER X.

LIME—MORTAR AND CEMENT—CLAY FOR BRICKS AND TILES.

On Limestones—Tests for Quality—Lime Burning—and on the Preparation of Mortars, Hydraulic Mortars, and Cements—with Tables of Weights, Quantities, and Strengths—on Concrete.

ALL stone in which carbonate of lime predominates is classed as calcareous stone, or limestone.

Acids act upon limestones in proportion to their porosity. The harder sorts are suitable for building, but not where there is much smoke in the air. Of this class, that found in the coal measures or in the Lias formation forms a good and reliable stone for bridges and general building purposes; the magnesian limestones found in the New Red Sandstone formation above the coal, varies greatly in strength according to its compactness. It is desirable to exercise very great care in their selection for structures exposed to the

weather, or in smoky or moist atmospheres. Another form of limestone will be found in the Portland stone, or granular limestone, rich in fossil remains of the Oolite and Lias periods, and capable of taking a fine polish; being excessively hard at places and soft in others, it requires care in selection. The Bath, Portland, and Aubigny stone represent the three classes of most durable oolites. They work well under the chisel for carving. In selecting stone for bridges, the factor of safety should not be less than 8; the stone should be actually crushed in the hydraulic press to determine its crushing weight; for general information Mr. Fairbairn's experiments are a sufficient guide.

STRENGTHS OF STONES (FAIRBAIRN'S EXPERIMENTS).

Grauwacke, from Penmænmawr		16,893	lbs. per sq. inch
Basalt, Whinstone		11,970	"
Granite, Mount Sorrel		12,861	"
" Argyllshire		10,917	"
Syenite, Mount Sorrel		11,820	"
Sandstones.	(Strong Yorkshire)	9,824	"
"	(Weak)	3,000 to 3,500	"
Limestones.	Compact (strong)	8,528	"
"	Magnesian (strong)	7,098	"
"	" (weak)	3,050	"

NOTE.—The crushing weight is given as the weight each specimen collapsed at in lbs. per sq. inch.

Lime is obtained from limestones by expelling the carbonic acid gas by heat; the lime then becomes *quicklime*, and is strongly alkaline. To this end, limes produced from different stones varying so greatly, the lime is classified as :—

1. Pure, rich, or fat lime (free from silicates).

2. Hydraulic lime (containing 10 to 30 per cent. silicate).
3. Cements (containing 40 to 60 per cent. silicate).
4. Pozzolanas (to which pure lime has to be added on account of the excess of silicates).

So important is the commercial aspect of the existence and quality of limestones on an estate, that a rough, but very reliable and simple method of analysis is given here to enable the owner to determine the class of lime that can be obtained from the stone.

Test for Limestones.—1. Select an average specimen; weigh it; calcine it in a crucible. Weigh it again when thoroughly calcined. The difference in weight is the quantity of *carbonic acid* and *water* expelled.

2. Take a specimen from 40 to 80 grains in weight. Reduce it to powder in a mortar. Add 3 times its weight of caustic potash and soda to it. Heat the mixture red hot in a silver crucible. When nearly cool empty the shell into a glass beaker. Add a sufficiency of warm hydrochloric acid slightly diluted with water. Evaporate the whole solution in a sand bath (a frying pan filled full of sand into which the vessel containing the solution is sunk, the pan being kept on the fire). Stir the solution continually towards the end, and when it becomes thick add 10 times the volume of *boiling* water. This dissolves every constituent but the silica. Filter the solution; wash the precipitate so obtained well with water; preserve this water used in washing, and the liquor from filtration. Dry and

calcine the precipitate washed. Weigh it; the result is the weight of *silica* in the specimen.

3. Add to the liquor and washing water (together directed to be kept in the previous process) solution of ammonia in excess. Let it stand till clear.

Then add lime water slowly, as long as a precipitate continues to fall (which is magnesia); wash the whole precipitate thus obtained by the whole process, dry and calcine it. Weigh it. Add to it the weights of *silica* and *carbonic acid*. Subtract the lime from the whole original weight of the specimen; the remainder is the *weight of lime* that can be got from the stone.

The *proportion* of silicates to carbonates decides the use the lime can be put to.[1]

If the stone is not magnesian, multiply the total quantity of carbonic acid in Process 1 by 2·3.

This result is the quantity of carbonates. The rest may be said to consist of silicates. If it should be magnesian stone, multiply by 2·12 instead of 2·3.

Fat or rich lime is obtained by calcining at a great heat, chalk, or limestone with few silicates and mostly consisting of carbonates.

44 per cent. of its weight is expelled or lost by the operation, leaving 56 per cent. weight of lime, $\frac{1}{10}$ to $\frac{1}{6}$ of which is wasted in cleaning out the kiln; $\frac{1}{5}$ to $\frac{1}{7}$ weight of coal to that of lime burned is the usual proportion.

Slaking of Fat Lime.—The lime above obtained is in the state of quicklime. If water is added, it is slaked; 9 parts water combined with 28·5 parts lime

[1] See classification of limes, p. 118.

chemically. It swells to 3 times its bulk and great heat is produced; it then falls to powder.

Quicklime should be stored in barrels, or in dry stores, and slaked rapidly when used.

Hydraulic Limes.—The limestones containing silica, magnesia, and alumina are used for this purpose. They are gray, blue, and brown in colour. They slake, when calcined, very slowly, therefore they are generally pulverised in a mill made for the purpose, and to be hired from any contractor. The stones are calcined as with fat lime.

To decide whether the result is *hydraulic lime* or *cement*, proceed as follows:—

Calcine a piece of stone in a crucible. Slake it to a paste with water. Make a ball of it. Put it in water. If *cement*, it hardens at once. If hydraulic lime, it takes from 1 to 14 days for it to set hard.

Hydraulic lime should be kept very dry, and not exposed to the air till wanted.

Pozzolanas, with Mine Dust.—These contain more silica than lime. If pure lime be added to iron mine dust, to a gray colour, say 2 to 1 of mine dust, a very hard cement is obtained. Lime for agricultural purposes should be prepared, if possible, on the estate. Limestones are best obtained by quarrying. Large bodies of water may be met with. These are best removed by a Pulsometer steam pump slung in chains over the site. They are less liable to becoming choked and are easier to fix and remove than engine pumps. For pumping out foundations they may be easily hired.

Mortar, Common and Hydraulic.—Lime and sand mixed together with water form mortar. The slower the water evaporates, the harder the mortar sets. It is made with rich limes.

Hydraulic mortar is made with hydraulic limes. Pozzolana added to common mortar makes it hydraulic. The sand used should be clean, sharp, and not too fine; if earthy, it should be well washed first. Sea sand should always be well washed. The proportions are:—

2·4 of sand to 1 of rich lime for common mortar.
1·8 „ 1 of hydraulic lime for hydraulic mortar.

The labour of mixing is, for common mortar per cubic yard = ·7 of a day's work of 1 man. A 2-horse pug mill for hydraulic mortars mixes 25 cubic yards a day. Their tenacities are as follows.:—

TENACITY OF MORTARS AND LIMES.

Limes.

Best hydraulic lime .	. 170 lbs. per sq. inch
Common „ .	. 140 to 100 lbs. per sq. inch
Rich fat lime . .	. 40 lbs. per sq. inch

Mortars.

Best hydraulic mortar	. 140 lbs. per sq. inch
Fair common „	. 50 „
Indifferent to bad „	. 20 „

NOTE.—Tests taken one year after mixing.

Concrete or Beton.—This consists of gravel or rough shingle with 5 to 6 times the volume of lime (hydraulic).

It only occupies $\frac{5}{9}$ to $\frac{5}{8}$ of the volume of the

materials used when laid and set. It should be laid in layers when used for foundations. Its crushing strain is 640 to 720 lbs. per square inch. The quantities required are:—

MORTAR QUANTITY TABLE.

(*For* 1 *Rod of Brickwork of* 4 *Courses* $\frac{3}{8}$ *Joints.*)

Proportion	Quality, &c.	Bushels	Cubic Feet
1 to 3 . .	Fat lime	20	25·7
	Sand	60	77·0
	Water	30	38·5
1 to 2 . .	Blue lias lime	30	38·5
	Sand	60	77·0
	Water	20	25·7
1 to 2 . .	Portland cement	26	33·4
	Sand	52	66·7
	Water	17	21·8
1 to 3 . .	do.	19	24·4
		57	73·1
		16	20·5
1 to 4 . .	do.	15	19·2
		60	77·0
		15	19·2

One load of mortar = 1 cubic yard and fills 40 hods.

Pointing brickwork requires, for flat joints $\left\{\begin{array}{l}\frac{1}{8}\text{ cubic foot mortar,}\\ \frac{1}{8}\text{ bushel cement.}\end{array}\right.$

Tuck joints require $\left\{\begin{array}{l}\frac{1}{8}\text{ cubic foot putty,}\\ \frac{1}{8}\text{ ,, mortar.}\end{array}\right.$

Concrete foundations to walls should be allowed to set well, and should have a 3-inch drain laid on the concrete along the enclosed side of the wall, if it encloses a garden or space.

Farm buildings should be pointed in cement 1 to 3.

The top corners and coping of garden walls, &c., should be in cement, 1 to 3 of sand.

Hydraulic mortars should be freshly mixed just before using.

Sewer and drainage man-holes should be built in cement 1 to 3; so also should green-house and hot frame walls. If common mortar dries too quick it will crumble.

Weight and Dimensions.

1 bushel of cement weighs 67 lbs.

1 barrel „ is 5 bushels.

1 hod for mortar measures $14 \times 9 \times 9 = 1134$ cubic inches. It holds 12 bricks or ½ bushel of mortar.

1 load of sand = 1 cubic yard, or 18 heaped or 22 struck, bushels.

1 bushel of lime weighs, average weight, 54 to 60 lbs.

Clay for Bricks.—There are three kinds—common clays, porcelain clays, and fire clays. Of the former class, those which are mixed with sand constitute a 'loam clay'; those mixed with carbonate of lime constitute 'marl'; this sub-division of the common clays never binds in burning. The expulsion of the carbonic acid in the calcining makes them friable. Clays mixed with a little sand make good bricks. It is the presence of silicates of lime, protoxide of iron, and salts of magnesia, such as the sulphates and carbonates, that make common clays easier to partially fuse, or become glazed in the kiln. Protoxide of iron greatly strengthens the bricks in hardness; it gives the clay a steely appearance that is changed to deep red when the bricks

are burnt. Silicates in too great quantity make the bricks apt to 'run' in the kiln, and come out out of shape. Excess of sand makes the bricks brittle. 1 to 5 is the proportion of sand to clay. 64 cubic feet of clay make 1,000 bricks.

Porcelain or Kaolin Clays contain silica and alumina in equal parts which combine with 2 equivalents of water, and are expelled by the heat of the kiln.

Granite rocks are overlaid with these classes of clays; and 9 parts of silica and the potash become abstracted by the action of the atmosphere. These are the clays used, but not found, in North Staffordshire. They are of a cream or light stone-colour to nearly white.

Stourbridge Fire-clays differ from the above by containing 2 parts silica to 1 of alumina, also some iron in the shape of a low oxide which determines their colour, varying, as it does, from white to drab yellow. They are chiefly found in the coal measures.

The *fuel used* to convert clay into bricks is from 7 to 9 cwt. of coal per 1,000 bricks. 3 men and 2 boys can make 16,000 bricks per week by hand. Good bricks should not absorb more than $\frac{1}{18}$ their weight of water.

The test of the broken section of a good brick is a rather glassy appearance, uniformity of section, and freedom from fissures or air bubbles.

Brick-making for sale, when practised on an estate, should be done by machinery, not by hand. Women may not be employed in brickfields (Factory Acts).

The water from the loams, marls, and clays, is ex-

cessively destructive to steam boilers, especially if not in regular work. (*Vide* Steam Boilers, Incrustation.)

Details of stones and bricks follow in the next chapter.

Burnt clay forms an excellent substitute for gravel, not being liable to 'lick up' or retain dirt or wet. One ton of slack coal should burn from 5 to 8 tons of clay; the pieces of clay should not be larger than 4 inches cube. It is called by railway permanent way men burnt ballast. A good open fire is first started, a barrow of clay lumps is then put on; when this becomes heated through, another layer of slack coal, then another layer of clay. When ceasing to increase the heap, secure the heat within by a good covering of clay, well rammed. Let the heap burn out and cool before disturbing. An outlet hole at the top and some air inlets at the bottom of the heap must be left, to secure combustion. In making roads through clay cuttings this should be practised.

For agricultural purposes and to decide whether a soil requires liming, as clay soils generally do, make a solution of the soil in water, taken in different places. Pour in 10 or 12 drops of hydrochloric acid; if sharp effervescence takes place the land does not require liming; if none takes place, liming will be beneficial. The effect of lime on strong clays, in encouraging a finer growth of grass, is most remarkable, but due care must be exercised in deciding whether the coarseness of the grasses is due to the want of lime, or the want of efficient subsoil or surface drainage. But when lime is so used to neutralise the acidity of the soil and

increase its fertility and stimulating powers, it must not be treated as a *substitute* for manure; a liberal application of the latter, on arable clays especially, should always follow the application of the former. A mixture of 2 parts salt to 1 lime is most effective in destroying mosses in grass land, and no doubt is excessively injurious to liver-fluke and such low organisms in sheep pastures. Gas lime is also applied to turf in these cases with advantage. The analysis of such clay soils is:—

Silica	0·35
Alumina	33·05
Lime	0·35
Protoxide of iron	0·45
Sulphuric acid	19·35
Water	47·00
	100·00

CHAPTER XI.

BRICKWORK AND STONEWORK.

On Brickwork and Stonework, with Details of Labour on.

Builders measure brickwork by the rod of $16\frac{1}{2}$ square feet, at $1\frac{1}{2}$ brick thick. Engineers always use the cubic yard as the standard of measurement.

A rod of brickwork is:—

$16\frac{1}{2} \times 16\frac{1}{2} \times 1\frac{1}{8}$ feet (reduced brickwork).
306·2812 cubic feet ,,
11·34375 ,, yards ,,

In practice, the rod is taken to be $11\frac{1}{3}$ cubic yards.

The stock brick measures $8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{3}{4}$ inches.

1,000 stock bricks occupy, when stacked, 52 cubic feet of space.

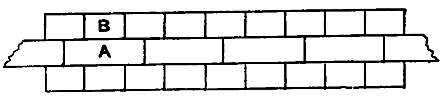
1,000 old bricks, cleaned, occupy, when stacked, 72 cubic feet of space.

In using old bricks they should be stacked, cleaned, and well weathered before use; those that have a good 'ring' only being used. Brick walls should be well coped in cement, and the last course, or even the last 3 courses, are better laid in cement for farm buildings and garden walls. All out-buildings should be well and sufficiently spouted, and the tenant made to under-

stand clearly that he must keep them open; in these days of *unexhausted improvements* by the tenant, it may prove advisable to provide against *unexhausted damage*, and nothing tends to ruin buildings, and brickwork generally, so much as insufficient coping and spouting, and the careless way in which spouts are broken and never replaced. It is this ceaseless petty expenditure in repairs and pointing that increases estate expenditure so greatly.

The actual working or laying of brickwork is purely a builder's or contractor's question. The labour on it is the point more nearly connected with the practice of a civil engineer, but a short explanation of 'bonds' and such technical terms may be useful. There are two systems of laying bricks in mortar, one English, the other Flemish bond. The former is the strongest; it consists in laying alternate courses of 'headers' and 'stretchers' as cross bricks and bricks laid lengthways are called; thus Fig. 17:—

Fig. 17.

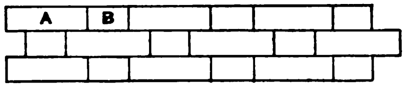


The course A is composed of stretchers; that marked B, of headers. In building factory or high chimneys four courses of stretchers go to one of headers.

Carelessly built brickwork brings vertical joints one above the other in a vertical line and greatly increases the tendency to splitting should the wall subside.

Flemish bond consists in laying alternate headers and stretchers in each course. The joints always break correctly; thus Fig. 18:—

Fig. 18.



One-fifth the volume of the bricks will give the volume of the mortar for good brickwork.

The men employed on a wall would be bricklayer, labourer, scaffolder. The approximate day's work of each, per cubic yard for walls and arches, is as follows:—

Bricklayer's Labour Table.

	Bricklayer	Labourer	Man Erecting Scaffolding
Ordinary laying	0·6	0·6	0·2
Brick-arching .	0·9	0·9	Variable

Buttresses.—These should be put up not without some considerable forethought and care. An architect or engineer should always be consulted when it is proposed to support exterior main walls with buttresses. Unless a secure foundation is obtained for the foot of the buttress, the wall is only further weakened. Insecure foundations to walls are the general cause of bulging. Subsidence, or cracks, may be ascribed to the action of water in the foundations. Kitchen garden walls should be wired for fruit trees. The practice of driving in nails is objectionable, and the pieces of cloth

harbour insects; the trees are easier protected from the frost, and, if blighted, easier to clean.

A Welsh fire brick measures $9 \times 4\frac{1}{2} \times 2\frac{3}{4}$ inches. They are suited for lining boiler furnaces with, and for setting boilers.

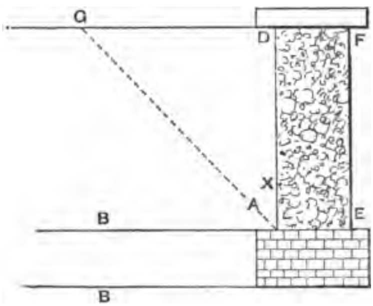
Stonework.

Dry Rubble Masonry.—This is greatly used for fencing walls in mountainous countries. A mason, *used to the work*, and one labourer will build per cubic yard as follows:—

	Days of 1 Mason and 1 Labourer
Rubble wall, built dry, per yard cube	·242
„ „ with mortar, per yard cube . .	·284
„ „ „ cement „ . .	·090

Rubble stonework is often used for retaining walls. 10 loads of rubble = 19·3 cubic feet, or 7 cubic yards.

Fig. 19.



Section.

This is roughly a man's day's work. Figure 19 shows the method of obtaining equilibrium between a bank and retaining wall, for all materials.

S = specific gravity of material forming the wall.

T = specific gravity of material forming the bank retained.

$$\tfrac{1}{2}\,AD\,AE^2 S = \tfrac{1}{6}\,AD^3 \times T \times \tan DAG^2$$

$\frac{1}{3}$ AD = point of pressure of the bank as at X.

The line of rupture GA has its distance DG as follows:—

For sand	. .	·618 × DA.
„ rubbles	. .	·414 × DA.
„ gravel	. .	·618 × DA.
„ earth	. .	·648 × DA.

If backward slope or 'batter' is given, $\frac{1}{6}$ of the height will suffice for backward slope. $\frac{1}{10}$ of the height to $\frac{1}{6}$ will suffice for the width at the foundations, $\frac{1}{10}$ for that at the top.

Stone for building being usually got near, an examination of existing buildings in the neighbourhood is the best guide. Stone staircases are very treacherous structures in case of fire. If the main staircase is stone, the back should be of brick or iron.

The stone splits when heated, often without warning. This is not the case with brick structures.

CHAPTER XII.

WOODWORK AND ITS PRESERVATION.

On Woodwork—the Strength of Beams—Sheet-piling—and on Timber and its Preservation from Decay—on Fire-proof Paints for Woodwork—with Speeds for Wood-working machinery.

THE action of certain acids contained in oak timber on iron, lead, and zinc, are of importance in all wood structures.[1] Zinc roofs should not be fastened to oak supports direct; iron nails perish in oak timber if not dipped in paint or tar. Lead is also slightly acted on by the acids contained in oak. For floodgates and such works exposed to water, acacia is very durable; teak does not attack iron.

The appearance of good timber, suitable for beams, bridges, &c., is as follows: the cellular tissue is firm and compact, not woolly; the fibrous tissue is firm and does not clog the teeth of the saw with detached pieces of stringy fibre. When freshly cut it is light and shining, not chalky in general appearance. Its weight per foot cube should be a good average.

Deal timber is thus classed, 12 feet to 14 feet long:—

[1] See Appendix. Specification for Creasote.

Sawn deal planks { 7 in. broad are called 'Battens.'
9 „ „ „ 'Deals.'
11 „ „ „ 'Planks.' }

The squaring up of timber as soon as felled is of importance. Seasoning takes about two years for joiner's work, and twice that time for larger sorts of timber, such as beams. Dry rot in timber is the growth of a fungus; insufficient ventilation is the cause, and complete removal of all tainted wood the remedy, with good top and bottom ventilation. Linoleum and oilcloths that are impervious to air will bring dry rot in floors if a space of 8 inches is not left round the walls. Impregnation with sulphate of copper is a preventive against dry rot. It should be done under a pressure of 30 lbs. per square inch. For wooden spanned roofs the following table is given, which gives the proportions for the relative parts:—

WOODEN ROOFS.

Span	Principal	Tie Beam	King Posts	Queen Posts	Small Queens	Straining Beams	Struts
20	4 × 4	9 × 4	4 × 4	—	—	—	3 × 3
25	5 × 4	10 × 5	5 × 5	—	—	—	5 × 3
30	6 × 4	11 × 6	6 × 6	—	—	—	6 × 3
35	5 × 4	11 × 4	—	4 × 4	—	7 × 4	4 × 2
45	6 × 5	13 × 6	—	6 × 6	—	7 × 6	5 × 3
50	8 × 6	13 × 8	—	8 × 8	8 × 4	9 × 6	5 × 3
55	8 × 7	14 × 9	—	9 × 8	9 × 4	10 × 6	5½ × 3
60	8 × 8	15 × 10	—	10 × 8	10 × 4	11 × 6	6 × 3

The roofs above 30 feet span are all calculated as queen trusses.

The simplest form of roof is given in Figs. 20 and

21. The latter figure represents the natural forces exercised on the roof.

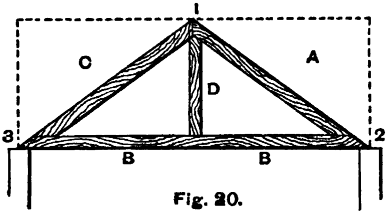
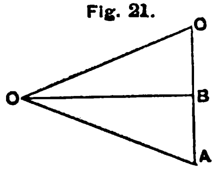


Fig. 20.

Section.

Fig. 21.



In this simple form of triangular truss (Fig. 20), A and C are the *principal rafters;* B B is called the *tie beam,* 2 and 3 are the *points of support;* 1 is called the *ridge;* D, if of wood, is called the *king post,* if of iron, the *king rod.*

In Fig. 21 the vertical line C A represents the direction of the vertical load on the ridge at the point 1, or $\frac{1}{2}$ the gross weight of the roof. O C and O A are the directions of the respective thrusts along the rafters; and the line O B is the horizontal tension along the beam. The relative forces now are:—

C = $\frac{1}{2}$ span of roof.
K = rise at ridge in feet.
H = tension along tie beam.
T = thrust along each rafter.

$$H = \frac{W\,C}{4\,K} \qquad T = \sqrt{\left(H^2 + \frac{W^2}{16}\right)}$$

This is the form of truss recommended for a wooden bridge truss; the parallelogram may be completed as shown by the dotted lines (Fig. 20). But on estates, the introduction of iron in place of wood is in every

way desirable for such structures as bridges, water-wheels, beams, &c. The life of wooden structures, such as quoted, would only be about double that time during which the interest borrowed would be repayable.

Beams applied to Wooden Bridges (*Safe Load*).—The following table gives details of safe loads for structures of both wood and iron. The calculation of the breaking weight under various circumstances being too lengthy and technical, the reader is referred to Clark's 'Formula and Equivalents for Mechanical Engineers,' where the subject is fully dealt with.

Permanent Loads on Bridges, &c.

For rough calculations the weight of the bridge itself may be assumed to be (in wrought-iron bridges):—

For	30	feet spans,	single line	5	cwt. per	foot run.
„	60	„	„	6	„	„
„	100	„	„	9	„	„
„	150	„	„	12	„	„
„	200	„	„	15	„	„

Dense crowds average 120 lbs. per square foot.

For flooring $1\frac{1}{2}$ to 2 cwt. per square foot, exclusive of the weight of the flooring, is generally allowed.

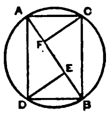
In store-houses from 2 to 4 cwt. per square foot.

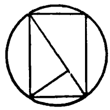
Safe Load in Structures, including Weight of Structure.

In cast-iron columns . . .	=	$\frac{1}{4}$	breaking weight.
Wrought-iron structures . .	=	$\frac{1}{4}$	„
In cast-iron girders for tanks .	=	$\frac{1}{4}$	„
In ditto for bridges and floors .	=	$\frac{1}{6}$	„
In timber (live load) . . .	=	$\frac{1}{10}$	„
„ (dead load) . . .	=	$\frac{1}{5}$	„
Stone and bricks	=	$\frac{1}{8}$	„

To Cut the best Beam from a Log.

Divide the diameter, A B, into 3 equal parts, A F, F E, and E B, and from E and F—draw the lines F C, E D, at right angles to A B—join A C, A D, B C, and B D, then A C, B D is the cross-section of the strongest beam.





To cut the stiffest beam, divide the diameter into 4 instead of 3 parts, as shown.

Fire-proof paint is to be used with advantage in wood partitions and general work.

The velocities for wood-working machinery are:—

Periphery of circular saws .	6,000 to 7,000 feet per minute
Rate of feed for circular saws .	15 to 60 „ „
Velocity of band for „ .	3,500 „ „
Velocity of gang saws, 20-inch stroke	120 strokes per minute
Velocity of screw saws . .	600 to 800 strokes per minute
„ periphery of planing machine centres . .	4,000 to 6,500 strokes per minute
Travel of work under above .	= $\frac{1}{20}$ inch per cut
Speed of squaring-up machine . centres	8,000 feet per minute
Speed of machine angles ($1\frac{1}{2}$ diameter)	900 feet per minute
Speed of mortising machines .	250 to 300 strokes per minute

1 horse-power required per hour for 75 feet superficial, pine.
1 horse-power required per hour for 45 feet superficial, oak.
Speed required for main shafting, 300 rev. per minute.

Self-feeding frames and guards should always be used for circular saws; otherwise knots of wood are

sometimes thrown out with great violence, and spirts of sawdust get in the man's eyes that feeds, if he stands behind the saw. Two india-rubber hook-tourniquets to arrest bleeding should be kept hanging on the saw bench, in case of accident. Men employed with such machinery should be insured, for injury as well as death. Never stand behind or in front of wheels revolving at a high speed. They may and do part.

CHAPTER XIII.

IRON AND STEEL.

On Iron and Steel Girders and Wire—and on the Strengths and Weights of Cast Iron, &c.

IRON is classed as wrought and malleable, or as cast-iron. Combined with a certain percentage of carbon it is classed as steel. When cast-iron girders are used, the load on them must be uniform, not variable. They should not be loaded to more than $\frac{1}{6}$ their breaking strain. The tension strain on wrought iron should not exceed $\frac{1}{4}$ breaking strain. The cost of a wrought-iron girder bridge per foot span for foot passengers only will be about 35*s.* As previously stated, the operation of designing iron structures is essentially that of a mechanical or civil engineer. To do any more than advise the substitution of iron for wood, where possible, would be going beyond the scope of this work. In the strength of cast-iron girders the following details may be of use:—

D = depth of girder in inches.
A = area of bottom flange in inches.
S = span in inches.
W = breaking weight.

When supported at each end, load in centre:—

$$W = \frac{25\,A\,D}{S}$$

When supported at each end, load distributed:—

$$W = \frac{50\,A\,D}{S}$$

Safe deflection $= \frac{1}{40}$ inch per foot span.

The annexed table gives the strength for cast girders of usual patterns for a distributed load in tons:—

CAST-IRON GIRDERS (BREAKING WEIGHTS).

Span in Feet	Depth in Inches	Bottom Flange	Breaking Weight in Tons
10	10	$6 \times 1\frac{1}{4}$	31
15	15	$8 \times 1\frac{1}{2}$	50
20	20	$10 \times 1\frac{1}{2}$	62
25	25	$13 \times 1\frac{3}{4}$	94
30	30	15×2	125
35	35	17×2	141

The safe load on chains (iron) thus: D = diameter in $\frac{1}{8}$ths of 1 inch, and W = safe load.

$$D = \sqrt{8\,W} \qquad W = \frac{D^2}{9}$$

TABLE OF SAFE WORKING LOADS ON IRON CHAINS.

Diameter of Iron	Working Load	Diameter of Iron	Working Load
inch	tons	inches	tons
$\frac{3}{8}$	1	$\frac{15}{16}$	6·2
$\frac{1}{2}$	1·7	1	7
$\frac{9}{16}$	2·2	$1\frac{1}{16}$	8
$\frac{5}{8}$	2·8	$1\frac{1}{8}$	9
$\frac{11}{16}$	3·3	$1\frac{3}{16}$	10
$\frac{3}{4}$	4·0	$1\frac{1}{4}$	11
$\frac{13}{16}$	4·6	$1\frac{5}{16}$	12
$\frac{7}{8}$	5·5	$1\frac{3}{8}$	13·5

Wrought-iron girders are generally used in the form of plate girders. For columns, both wrought and cast-iron is used. The nature of the work to be supported regulates the design of girders, and space will not admit of detailed description here. Most founders keep girders and columns in stock for every sort of work. Steel, if used for boilers, should be drilled, not punched, to receive the rivets.

Iron gates are a great economy near the farm, where they are constantly being opened and shut; but as a general rule they are not constructed to be sufficiently stiff. Iron stranded wire is used for fencing. No. 4 galvanised iron telegraph wire is used with success in Scotland for the same purposes, and is more durable and less expensive. The writer has found cast-iron gate posts of use in certain places. The weight of metal pipes is as follows:—

D = outside diameter of pipe in inches.
E = inside " " "
W = weight of 1 linear foot of pipe in lbs.

$$W = K \times D^2 - E^2$$

K = 2·45 per cent. iron.
= 2·64 " wrought iron.
= 2·82 " brass.
= 3·03 " copper.
= 3·86 " lead.

CHAPTER XIV.

THE GENERAL FORMATIONS IN GEOLOGY FAVOURABLE TO THE EXISTENCE OF MINERALS.

On the Geological Features that justify Exploration for Minerals, with Notes respecting the Development of Coal Mines.

THE periodical depositions, denudations, and upheavals that have modified the original section of the earth's crust may occasionally be taken advantage of, and minerals may be wrought at a shallow depth in comparison with their proper geological position.

The crystalline rocks represented by granite form the fundamental rocks of the earth's crust. Granites, with this series of great thicknesses of crystalline rocks, are called the primary rocks. The minerals found in them consist of tin, iron, zinc, lead, copper. Next above granite come the crystalline schists. Of this class are gneiss, quartz, and limestone. These are the richest of metalliferous strata included in the primary rocks.

Passing further come the transition formations, or rocks largely present in Cumberland and Westmoreland, the mountains of Wales, and the Cornish rocky coast. They are rich in mineral ores, silver, lead, zinc, copper, cobalt, manganese, bismuth, antimony, and sometimes

iron. Their surfaces, when calcareous, and not silicious, are capable of considerable agricultural fertility.

Above these transition rocks comes that great secondary formation that the miners term 'the world's coal-hole.' This secondary formation is of immense thickness. The strata lie as follows, proceeding upwards from the transition rocks :—

1. The Old Red Sandstone.
2. The Coal Formation.
3. The New Red Sandstone.
4. The Lias.
5. The Oolite.
6. The Chalk.

It is to be observed that some of these are not always deposited.

The Old Red Sandstone, rich in marine fossils and impressions of marine plants, corals and testacea, is poor in minerals. It is to be seen at the surface in the county of Hereford.

The coal formation consists of limestones, ironstones, coal seams, and ligneous deposits. The lowest stratum is called mountain limestone. Derbyshire is a fertile instance. It is important to recognise that the *true* English coal measures, or workable seams with their clays, lie *above* the mountain limestone.

The New Red Sandstone now follows. Lancashire, Cheshire, part of Shropshire and Staffordshire, are all of this formation. It follows the course of the river Trent to the Humber. It produces the rock salt and brine seen at Nantwich and Shirley Wich. The pebble

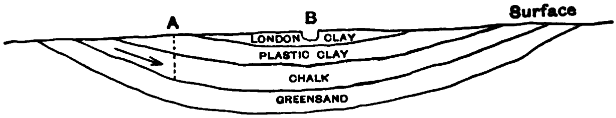
beds overlying this stratum of sandstone occasionally contain water to a great extent, causing expense in pumping or 'tubbing back,' when sinking through them for coal.

Following the New Sandstone measures we have the Lias formation, containing the fossil remains of enormous fish lizards 20 to 30 feet in length. It contains no minerals that are workable, indeed rarely any except a carbonate of copper. It is valuable for hydraulic limes (*see* Lime, chap. x.). It is the dreaded 'blue slipper' of the railway engineer. Lyme Regis is entirely lias; it is a good subsoil for dairy farming. Leicester, Gloucester, Warwick, and Somerset are instances of its value agriculturally.

The Oolite (Jura limestone) follows next above the Lias. It consists of marl, sand, lime and sand stones. The Lower Oolite is separated from the Lias limestone by the *Lias* clay, the lower from the Middle Oolite by the *Clunch* or Oxford clay, and the Middle from the Upper Oolite or Portland Oolite by the *Kimmeridge* clay. This applies in England only.

The Chalk or Wealden formation now comes. Its agricultural value speaks for itself. Fig. 22 shows its

Fig. 22.



Section.

section in London at the estuary of the Thames. B is the bed of the Thames. It will be seen how a bore

sunk at A into the chalk will yield an artesian supply of pure water that cannot be polluted.

It may be now said definitely that workable coal does not exist under the Wealden stratifications in the south-eastern counties of England.

The Tertiary formation above the plastic clays afford gypsum and calcareous deposits.

Above this come the alluvial deposits. The fossil remains are those of the tapir type, or 'Pachydermata.' They do not afford any minerals; indeed it may be said the super-tertiary deposits are not unlikely to be coeval with the existence of man. Their examination in America is of the greatest interest to the geologist on this account. In dealing with all tertiary formations it should rather be of their present place than of the age to which some of them belong.

Coal and Iron.

In general the search for coal should be first conducted by means of a preliminary comparative table of sections obtained in the neighbourhood. These may be then laid before an experienced mining engineer for his opinion on the dip, nature of roof, probable quantity of water to be met with, number and quality of seams, facility of transport for the coal when won. This decides the question of boring or sinking direct.

It is then advisable for the owner, through his engineer, to draw up a statement of terms on which he will grant a lease of the supposed minerals.

In general it is most unwise for an owner to bore for coal at his own expense or to work coal mines. A

retrospective experience of the relations between capital and labour are not sufficiently encouraging for me to recommend an owner to lock up his capital on terms to be dictated by others or by events. On this point I write distinctly as a mining engineer. The want of confidence invoked, and of late years fomented greatly by the recognition of the field of labour as an area for the display of party politics, is driving capital rapidly from its legitimate channels, and one result only can follow—in place of this country being, as it has been, the workshop of the world, its home industries will be starved, home ties will be severed, and both capital and labour will leave the country. There is ample field for legitimate employment of capital in this country; and those who, with inflammatory utterances for the sake of party politics, foment the labour market and its chronic discontent, which might so well be turned to a feeling of national ambition to rise, and which is the secret of all success in competition whether of the nation or of the man, should reflect that when capital and labour are driven from the country their unpatriotic occupation of political agitation will be gone, and the majority of the very class whose interests they profess to watch will be unemployed. The well-worn statement that the employment of English capital in America and Australia is a proof of the abundant wealth of the nation that finds it requires to be compared with the question, what proportion of the whole is employed at home in remunerative industries, and with the fact that the foreign industries thus created compete with home industries on a ridiculous and

unfair basis. In the Colonies a man *has* to work, the alternative is starvation; at home there is rapidly becoming but little to do, and those who would work are led on by false hopes to ask a prohibitive price for their labour. Free trade as a policy requires a free and open labour market. This is impossible where it is made the scene of party politics.

On these experiences, gained at home and abroad, I advise owners to let others develop these minerals. So also is it with iron. The proportion of capital to be locked up is out of proportion to the income of the owner, and the rate of interest too uncertain to warrant him becoming his own smelter.

It may be observed that by the basic process of Thomas & Gilchrist many ironstones containing prohibitory quantities of phosphorus may now be made into steel direct.

PART III.

ON EARTHWORK AND ROADS.

CHAPTER XV.

EARTHWORK AND ITS MEASUREMENTS.

On the Measurements of Earth—Tables of Labour on, and Notes on the Retention of Earthwork, and Retaining Walls.

THE extent of the friction of the particles composing a bank of earth is the extent of its stability. All soils possess what is called an angle of natural repose—that is, when heaped up, they assume a definite slope. The tangent of that angle is the co-efficient of friction. The usual way of describing a slope of earthwork is to state the proportion of its horizontal breadth to its vertical height; this ratio is called the *reciprocal* of the tangent of inclination. But for general practice it will suffice to take the following angles of stability for earthwork, it being borne in mind that if the earth is tipped in making an embankment it will assume its angle of repose naturally:—

For dry sand, clay, mixed earth	from	37°	to	21°
„ damp clay	„	17°	„	14°
„ shingle, gravel	„	48°	„	35°
„ peat	„	45°	„	15°

The most frequent slopes are those called $1\frac{1}{2}$ to 1 and 2 to 1, whose angles of repose are $33\frac{1}{2}°$ and $21\frac{1}{2}°$ respectively.

In the particulars given in the chapter on the Treatment of Rivers, further particulars are given of labour and the facing with stone and turf of such embankments as are used for confining flood waters. Reference to the tables therein will give the cost of labour on such work.

The weight of a cubic foot and yard of earthwork is as follows:—

WEIGHT OF EARTHWORK.

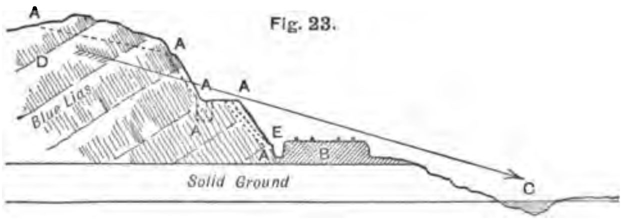
Material	Per Cubic Foot	Per Cubic Yard
	lbs.	lbs.
Chalk	117 to 174	3,160 to 4,730
Clay	120 „ 135	3,240 „ 3,645
Gravel and shingle .	90 „ 110	2,430 „ 2,970
Marl	100 „ 119	2,700 „ 3,210
Sand (dry) . .	89	2,400
„ (wet) . .	125	225
Shales . . .	162	4,370

The proportions of getters, fillers, and wheelers, for 50 yards run should be as follows:—

	Getters	Fillers	Wheelers
In loose earth-sand .	1	1	1
In compact earth .	1	2	2
In marl . . .	1	2	2
In hard clay . .	1	$1\frac{1}{4}$	$1\frac{1}{4}$
In compact gravel .	1	1	1
In rock . . .	3	1	1

Slips and their Treatment.—These slips, as subsidence laterally is called, are due to the action of water; they commonly occur in the blue lias formation, and in the plastic clays. The Midland and Great Northern Railway Companies have had great trouble with slips near London. The writer had an experience of them in the neighbourhood of Lyme Regis. Fig. 23 shows a cutting 'stepped' and drained for slips. Here the tendency was for the 'blue slipper' contained in the bank D to slide in the direction shown by the arrow, completely blocking or carrying away laterally the railway at B in the direction B C. The drains A A A A were cut to intercept the water, and were made as trenches filled with large stones. At E a drain was

Fig. 23.



Section.

carried parallel with the line, cut down to the level of the solid ground. The water is thus intercepted in its natural course to a brook at C. Embankments of course should never be formed of any such material likely to slip.

The pressure from slips will overturn any retaining wall unless the bank is stepped and retained by a wall with a good batter to it.

Inasmuch as most of such retaining walls come under the head of *surcharged retaining walls*, it is desirable to examine the conditions of stability of these walls when loaded, and to provide accordingly.

Firstly, then, for the ordinary retaining wall for a cutting the following formula and table is :—

ORDINARY RETAINING WALLS.

Batter of Wall	Clay	Sand	Clay	Sand
1 in 4	·083	·029	·115	·054
1 „ 5	·122	·065	·155	·092
1 „ 6	·149	·092	·183	·118
1 „ 8	·184	·125	·218	·153
1 „ 12	·221	·160	·256	·189
Vertical .	·300	·239	·336	·267
	E : W :: 4 : 5		E : W :: 1 : 1	

E = weight of earthwork per cubic yard.
W = „ wall „ „
H = height „ „ „
T = thickness „ at top „ „
T = H × the number in the table.

SURCHARGED WALLS.

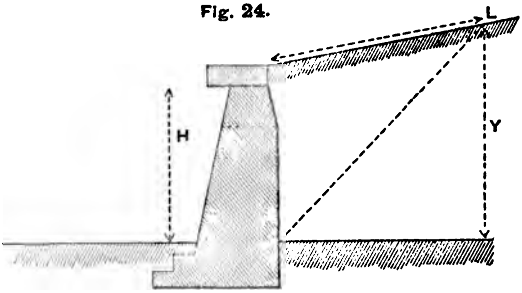
The height H is to be measured off up the slope to L. Y is a perpendicular line let fall from it. T, the mean thickness of the wall, is :—

$$T = \cdot 77 \times \text{tangent } \frac{a}{2} \quad \frac{\sqrt{W}}{R}$$

The angle A is the natural slope or angle of repose of the material; W is the weight of the wall in lbs.;

R is the weight of the earth per cubic foot behind the wall.

Fig. 24.



Tangent Table for $\frac{a}{2}$ in foregoing Formula.

Tangent $\frac{a}{2}$ for gravel and sand	=	·488
„ „ shingle . .	=	·510
„ „ earth, wet .	=	·532
„ „ London clay .	=	·637

Labour in Excavation and Filling.

Excavating per cubic yard.	Days of 1 navvy.
Earth	·045
Sand	·060
Clay	·100
Gravel	·150
Chalk	·200
Rock (requiring blasting) . .	·450

For getting out trenches such as foundations, add one-third to the above.

	Days of 1 navvy.
Filling barrows with one yard cube earth	·045
„ „ „ „ clay	·052
„ „ „ wet clay.	·056

CHAPTER XVI.

ON THE CONSTRUCTION OF ROADS.

On the Construction and Maintenance of Roads, and on Portable Farm and Mineral Railways—Their Cost, &c.

In the previous chapter the general details in connection with earthwork were given. The estimation of the cubic contents of earthwork to be removed as a cutting, or formed as a bank, requires long practice and some considerable surveying knowledge, more than can be expected except from contractors of long standing. So that should such estimates be really required, a contractor's opinion should be taken, and the work let out as a contract. In the construction of roads it rarely occurs that any great difficulties are met with in the matter of earthwork; the chief obstacles are in crossing swampy places or peat moss, in getting a good foundation for the road, and in the absence of proper natural materials. The sectional curvature—*i.e.* the curve from side to side of the road—should not be greater than will drain the road, otherwise the centre will always be chosen by carters, and the road will be worn down into a wavy condition, which is, in winter, very destructive to the foundation. 1 in 164 is the gradient on which a horse can perform his work

both up and down hill with the least waste of his strength. The roundness or sectional curvature of the road above alluded to may be made 1 in 33 to 35.

The repair of roads, to be economical, should be little and often; no work should be done in the way of re-metalling until the autumn rains have set in. To keep farm roads in order, where steam power is available, a stone-breaking machine should be used. Indeed, stone-breaking by hand is slow, expensive, and in every way unsatisfactory, except it be regarded as a charitable means of employing labour unfitted for active work; but bad roads are the means of many accidents and loss of time, so that the old men on an estate can be better employed keeping drains open, &c., than in such work.

Stone-breaking machines are made of all types. Their cost to work is about threepence per ton of stones broken. They should be supplied with travelling jaws to break stones to different sizes. A stone-breaking machine constructed by Marsden and Co., of Leeds, costing 190*l*., gave the following results:—

TRIAL OF STONE-BREAKERS.

Size	Tons per Hour Broken	H.-P.	Total Weight	Weight of Frame	Price on Wheels
15 × 7	4¾	6	108 cwt.	54 cwt.	£190
24 × 12	8½	12	377 ,,	80 ,,	Fixed

The use of these stone-breakers is not fully recognised by agents. The gauge for the size of farm road stones should be a 2-inch ring, through which any stone picked up at random should pass. The 15 × 7 sized

machine is about the size required for an estate. The material that has been broken should be laid on in thin layers in wet weather; except the stones are broken, they can never bind. Some slight sprinkling of fine gravel or earth may be required to ensure this. When stones that are well broken do not bind, it is a sign of an insecure foundation; the road 'works up' under the load, and if attention be paid to the road just in front of the wheel of the waggon going on it, it will be at once seen that much of the horse's labour is expended in crushing down the ridge of road that has 'brackled up' just in front of the wheel base.

In adding fresh material, the old road should be picked up to a depth of 6 inches. The drip from overhanging branches of trees is injurious, and cottages should not drain across the road.

The maximum or *ruling gradient* for any road should not be more than 1 in 30.

Whinstone and such durable stone is suitable for repairs and for road bottoms. For back roads up to a private house, Mount Sorrel chips form a good top, and are clean and durable; so also are Mount Sorrel blocks 4 inches cube, for yard paving, and especially for stable yards, rapidly drying and never becoming slippery, besides being excessively durable and neat in appearance.

The Mount Sorrel quarries are situated near Leicester; the blocks are delivered ready for use.

On sharp curves or bends in the direction of the road, when the banks are high and level with the horse's head, the fences on either side should be posts

and rails, to allow of persons driving seeing round the curve; where traction engines are much used this is a most necessary precaution.

The side drains to the road, especially at gateways leading into fields, should be cleaned out in the autumn ready for the winter, and if repairs are carried on late into the year care should be taken with regard to small stone heaps that they are kept well clear of the roadway, otherwise they become obliterated in falls of snow and become dangerous to traffic.

In laying out new roads, sharp curves are to be avoided; the ruling gradient, as stated, is not to exceed 1 in 30, the rotundity of the road 1 in 35; and in taking levels and averaging the reduced level of the section, as explained in the article on Levelling, the gradients are to approach 1 in 164, as near as possible.

Gateways into arable fields should have a liberal sweep allowed them, in turning off the main road, to allow of a steam ploughing engine entering in easily. Where side drains to farm roads pass under the entrance to arable fields, proper culverts should be constructed to bear the weight of engines passing in and out. These of course should be of brickwork set in cement.

Turnpike roads are by statute 30 feet in width, averaging 6 inches in the centre above the sides in rotundity.

Footpaths measure 6 feet, with an inclination of 1 inch towards the road. Side drains are 3 feet below the surface of the road.

Rough method to gauge road metal :—

L = length of side of gauge in inches—*i.e.* the slope of the heap.

B = number of bushels of metal required per linear yard of road.

$$L = 12\tfrac{1}{4}\sqrt{B}$$

2,700 cubic inches being = 1 'heaped bushel.'

The traction power of horses is :—

Rate in miles per hour . .	=	2	3	3	4	4½	5
Force exerted in lbs. per horse .	=	166	125	104	83	62	41

Resistance in lbs. per ton on different roads exclusive of gravity :—

	Lbs. per ton.
Stone tramway	20
Paved road	33
Macadam road	44 to 67
Gravel	150
Soft ground	210 to 250

Care is to be taken to metal extra thickly the crown and slopes of brick arches.

Under the head of roads we come to portable railways, for quarrying, lime burning, or for use on large fields worked by steam in the operation of liming or manuring.

Mr. Grant's Portable Railway.—This is essentially a farm railway. Its prime cost may be estimated as follows :—

	£	s.	d.
Rails per pair, with tie-bars, 22½-inch gauge, per yard (lengths are 5½ yards)	0	3	0
Turn-tables, each.	5	10	0
Ballast truck, with automatic tailboard and brake, each	10	0	0

	£	s.	d.
Side truck, to hold 1 cubic yard	8	10	0
Harvest truck, to hold the half contents of a farm waggon	13	0	0

Average cost for a large farm, 200*l.* complete.

A smaller gauge is also made for making private roads and walks.

It is self-evident that in dealing with the liming or stoning of a large field, or in taking off turnips in wet weather, labour is saved and the trampling of the ground by carts avoided. The trucks tip to the side clear of the road. Where land is cultivated by steam I consider the use of such railways part of the entire system. Where engine power is to be used, such plant as that constructed by the Castle Engine Works at Stafford is required. Excellent practical results have been obtained with both. Work has been done over the grass lawn forming John Evelyn's Walk at Albury Park that could not otherwise have been accomplished without destroying the turf, and the writer has witnessed many successful instances of such systems in the Colonies, Ceylon, and elsewhere.

The use of steel in the construction of the trucks is desirable; experiments conducted by the writer on the surface and underground has shown the adaptability of steel to such a purpose. Such steel waggons are constructed with a convenient rim to them on steel wheels by the Gildersome Foundry near Leeds. When Mr. Grant first introduced his railway plant it was of iron. The writer advises steel rails and steel points; the portable railway is easily conveyed about or stored. In

laying down in fields, advantage is to be taken of natural gradients, so as to work up-hill empty.

In executing work over turf land these tramways are invaluable

A feature in working over turf land is the condition of roads or rides in woods. These should be much better drained than they generally are. Labour spent in forming good roads out of large woods soon repays itself in the saving in damage and expense when drawing out timber, a point often overlooked. If sown down as rides, then the following mixture and quantity required per acre will form a good sound drive. It is from experiments of Mr. Robert Brown, of Wass:—

GRASS MIXTURE FOR RIDES.

	Lbs.
Dactylis glomerata, or rough cocksfoot grass	3
Anthoxanthum, or sweet-scented grass	4
Festuca duriuscula, hard fescue grass	2
Bucetum elatius, tall fescue grass	1
Alopecurus pratensis, meadow foxtail grass	2
Poa pratensis, smooth-stalked meadow grass	3
Poa trivialis, rough-stalked meadow grass	5
Poa nemoralis, wood meadow grass	6
Phleum pratense, Timothy grass	1

When planted they should be rolled and bush harrowed; when fairly up they should be well rolled, and cut annually at first.

All bridges and culverts on roads must be constructed to carry the weight of traction engines, say 10 tons; these engines (10 H.-P.) can take 12 to 15 tons up a gradient of 1 in 12, or 30 tons load on level ground.

CHAPTER XVII.

ON QUARRYING, BLASTING, AND THE USING AND STORAGE OF MODERN EXPLOSIVES.

On Blasting, Quarrying, and the Use of Modern Explosives, with Rules for the Guidance of Workmen in the Using and Storing of Explosive Compounds.

Rock that cannot be split with a pick may often be worked off by boring holes and using blunt steel wedges. This per cubic yard has been estimated at ·04 of a day's work of one man, but it varies greatly. Failing all measures, the use of explosives must be resorted to. These are blasting powder, dynamite, and tonite or cotton powder.

Blasting powder may be used when the following are the circumstances. Where the rock is dry and not too hard, such as in the sandstone strata, the operation consists of boring a hole in the rock about 2 inches in diameter, from 1 to 10 feet in depth, and charging the same with powder in repeated small charges well rammed with a *wooden* or *copper rammer*, not with any iron or steel tool; dry clay is always to be used as tamping. The tamping should be not less than 8 inches. The fuze to be used is Bickford's safety fuze. Its rate of burning should always be tested by burning a length first, and then a suitable quantity, say 2 feet,

erring always on the side of safety, should be inserted on the top of the powder, and a little loose powder poured into the hole after; the tamping is then inserted, care being taken not to crush the fuze. The man in charge then satisfies himself that his fellow-workmen have withdrawn to a place of safety, and, if such is the case, lights the fuze and retires himself to await the explosion.

If the shot misses fire, after allowing ample time to elapse, a fresh hole should be put down close to the other; to unram the missed charge is certain to end in an accident, and so well known is this that, in mining, the 1872 Mines Regulation Act says, '*A shot that has missed shall not be unrammed.*' The explosion of the second shot explodes or destroys the first charge hole.

The weight of powder required for a blast may be thus estimated. Powder takes the line of the *least* resistance when ignited to liberate its expansive gases. This is the shortest line from the bottom of the bore hole to the surface of the rock at any point, then

$$\text{powder required in lbs.} = \frac{(\text{line of least resistance in feet})^3}{32}$$

1lb. of blasting powder occupies thirty cubic or 38·2 cylindrical inches 1 inch diameter.

It may not be stored in a dwelling-house unlicensed (Explosives Act); neither may any detonating or percussion caps of the fulminate class be stored with it.

The principal labour in thus quarrying rock is in

'jumping' or boring the charge holes. To do this effectually two men and one boy are required. The men strike the top of the jumper with hammers, the boy turning it round slowly meanwhile. Another method is called churning, in which two men raise the jumper and let it fall back in the hole again. Then a day's work per man by each process gives—

	Cylindrical inches of holes
Jumping in granite	100 to 150
Churning	200
In limestone	500 to 700

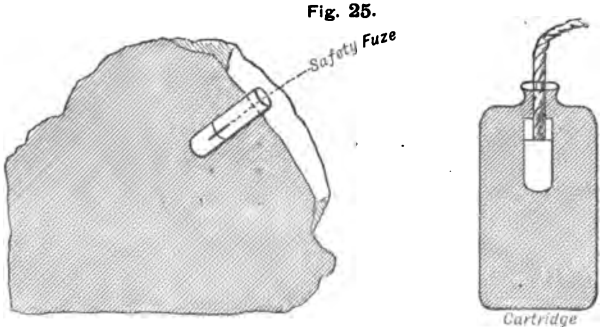
The jumper requires sharpening once for every foot bored in granite, and to be resteeled every 15 to 20 feet.

Gunpowder is not an economical agent in sinking wells, splitting roots of trees, or very hard rock. For this purpose dynamite and tonite are employed. Dynamite possesses some dangerous properties, such as freezing; the operation of thawing is and has been proved to be a dangerous one, except in the hands of skilled men. It is quite unsuited for estate work. Tonite, or cotton powder, is free from all these objections. That manufactured by the Tonite Company at Faversham the writer has used for several years with perfect immunity. To use this explosive for sinking or blasting roots, 4-ounce cartridges are most suited. Sextuple detonators are used to explode the cartridge with a length of safety fuze attached. Thus Fig. 25 shows a cartridge in a root ready for firing.

The bore hole need not be tamped; a piece of turf pressed into the mouth of it is sufficient. Care is to

be taken only to use the proper pair of fuze nippers supplied. The quantity of fulminate in the sextuple detonators is much too great to run any risk of explosion. The fuze must touch the fulminate, and the mouth of the detonator very lightly nipped to prevent the fuze drawing out.

Fig. 25.



Sectional.

Tonite may be stored only as directed by the Inspector of Explosives (local), according to quantity, &c.

Explosives may not be used in a fishery district in rivers, or to destroy fish.

The cost of splitting 157 roots of trees with tonite was as follows; one man and one boy employed :—

Roots split up per day, average .	5	
Shots per root „ . .	2	
Fuze „ „ . .	2	feet.
Detonators „ „ . .	2	
Tonite in 4-oz. cartridges, per root .	2	cartridges
„ 8-oz. „ . in all	12	of these were used
Augers broken altogether . .	1	

Cost.

	Per root s.	d.
Tonite (2s. per lb.) in 4-oz. cartridges . .	1	0
Fuze and detonator	0	3½
Average cost	1	3½

Adding to this cost per root for explosives, the labour per day at 7s. 6d., we have, for five roots split as an average day's work, to take 1s. 6d. as the labour on each root, so that it is as follows:—

	Per root s.	d.
Explosives	1	3½
Labour	1	6
Total cost	2	9½

The average cost per root split with wedges was 3s. 4½d.

These roots were exceptionally hard stumps, some of which had defied wedging altogether.

The saving of time by employing tonite was very great. The concussion of tonite being very great, the use of it near glass windows requires care. It can only be fired by detonation; letting a cartridge fall is perfectly safe. Detonators and cartridges may not be stored or sent together.

Rules for Blasting.

Gunpowder.

1. The *person in charge* of the magazine shall see that all engaged are sober and acquainted with the work. He shall only issue the actual quantity required in a closed tin can, and shall take every pre-

caution required under the Explosives Acts for the safe storage and delivery of the powder.

2. No light shall be applied to any fuze except by the *chargeman* after he has warned the rest of the men at work and satisfied himself that they are out of danger.

When more than one blast is fired at once, the lighters should take care that they do not pass a shot hole in seeking refuge.

The shots in this case will be counted off by the chargeman as they explode, and he alone is to examine the after-effect.

3. A missed shot shall not be unrammed.

4. Mines Regulation Act tools are to be used.

5. Tamping, except with dry clay only, is forbidden.

Note.—Should an accident unfortunately occur, the ignited clothes of the injured are to be extinguished with a blanket. The eyesight, if damaged, to be treated by pouring in sweet oil and immediately protected from all light (no attempt to see on the part of the injured person to be allowed). Burn mixture —viz. Carron oil and lime—to be freely applied to the burnt surfaces, which are then to be lightly covered with cotton wool.

For this purpose—

1 pint sweet oil,
2 gallons burn mixture,
3 blankets,
20 lbs. cotton wool,

per 15 men employed, to be kept on the spot, for which

the person in charge of the magazine is held responsible that they are there ready for use.

Dynamite.

1. Thawing to be done with hot water, as directed by the makers. One man only to undertake it.

2. No shot to be touched with a rammer after the fuze is inserted.

3. The fuze *first* to be placed on the detonator, nipped with the *special nippers* only, and then inserted in the cartridges.

4. Rules 1, 2, 3, 4 and 5 (Gunpowder), apply equally where dynamite is used.

5. Detonators and dynamite are not to be stored together in the same places.

Tonite.

The same as dynamite.

The provisions of the Explosives Acts are to be observed strictly.

When electric firing-keys are used, the master chargeman will not connect up at all till the men have been warned and have retired.

In sinking, double the usual time to be allowed for shots to explode. The men to leave first, one only (the chargeman) to remain to light the shots.

Caution.—The fumes of dynamite and tonite are dangerous. A proper fan blower is to be attached and rotated before the men descend.

In sinking wells electrical firing is desirable. A

portable firing-key with directions is manufactured by Messrs. Apps & Co., of London, which fires on depressing the key. No battery is required. Its price is about 3*l.* to 4*l.*

A number of shots may be fired simultaneously by means of electricity, but not when connected in circuit. A different form of fixing apparatus is required, called a *multiple arc firing battery.* A portion of the whole current passes through each fuze simultaneously; this grouping of shots is much more effective than single blasts, but if carried out on a large scale it is wise to have an electrician in charge, whilst on a small scale it is not desirable, except perhaps in well-sinking.

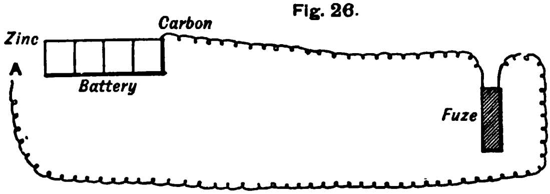
In blasting under water recent experience has shown that the explosive must be in actual contact with the object to be removed to effect demolition satisfactorily. The electric wire suitable for this work is No. 16 BWG G.P. covered, technically known as 'Morse wire.' An 8-oz. tonite cartridge will generally suffice to remove a sunk pile or large stone. If a grappling iron and chain be kept at hand, if the obstruction be a large root, an opportunity may be seized of getting it out, as roots frequently come to the top after the shock of the explosion, when they can be got into shallow water. The cartridge may rest on the obstruction; the column of water above it acts as a tamping; thus heavier charges will be required in shallow water. Four feet of water is an efficient pressure for 6 to 8-oz. cartridges.

The connections of an ordinary battery to a 'quantity' fuze are shown in Fig. 26.

On closing the circuit by touching the zinc pole of the battery with the end of the return wire A, the fuze explodes.

Fuzes, if required for single blasts, may be either those known as *quantity*, or as tension fuzes, but those for grouped shots should be *quantity* fuzes. The former explode by the heat generated by the passing

Fig. 26.



current in a fine platinum wire igniting a skein of gun-cotton; thus the circuit s not broken; the latter, or tension fuzes, explode a mixture by the electric spark leaping over a minute break in the circuit in the fuze. Thus with one Smee's cell the quantity fuze may be tested by the passage of a current from the cell, which is too weak to heat the wire when the charge is actually put down ready for firing. This test cannot be taken with a tension fuze.

PART IV.

STEAM AND MACHINERY.

CHAPTER XVIII.

STEAM BOILERS: VERTICAL, TUBULAR, AND HORIZONTAL.

On Steam Boilers, Areas of Fire-grates, Safety Valves, &c., with Rules for Working Pressures, Testing Steam and Water Gauges, with Notes on Steam Saw-mills, and Sizes for Vertical Cornish and Lancashire Boilers, showing their Proportions.

On this subject it may be said that the work to be done, and the fuel to be obtained, govern the type of steam boiler to be used. For light work a small engine and vertical boiler, such as those constructed by Messrs. Nicholson of Newark, are most useful; they will burn peat, sawdust, or coke; the engine is of the overhead crank type.

For driving fixed machinery like a saw-mill, the horizontal boiler of the Cornish or Lancashire type is most desirable. For rapid generation of steam a vertical boiler with the now well-known Field tubes arrangement is used. It is not so much our province to recommend one type of boiler before another, or one firm of boilermakers in preference to another, as to

give such details as regards the generation of steam as will enable the reader to apply steam power for the several purposes to which it is recognised to be applicable on landed estates generally. But a word of caution may be introduced here. When necessary to purchase a boiler, either proceed to the *works* where boilers may be seen in course of construction, or consult an engineer who is professionally qualified to prepare the specification. Avoid dealers in second-hand machinery, at all events when boilers are in question. The purchase of second-hand boilers is only possible when their previous history is known, and it is to be regretted that Government does not insist on the date of first use and thickness of original plates being indelibly marked on each plate.

Before preparing details for a boiler specification the following general properties of fuel in raising steam should be studied.

When the feed water is introduced into the boiler at 212° F., or boiling point, the power of different fuels to evaporate the water is as follows:—

Evaporative Power of Fuels.

1	lb. of	coke	evaporates	9	lbs. of water.
1	,,	coal	,,	9	,,
1	,,	slack	,,	4	,,
1	,,	oak (dry)	,,	$4\frac{1}{2}$	,,
1	,,	pine	,,	$2\frac{3}{4}$	,,

Coked coal increases $\frac{1}{10}$th in bulk to store, but loses $\frac{1}{3}$rd in weight in the process of coking.

$\frac{3}{4}$ of a foot of area of firegrate is required to evaporate 1 cubic foot of water.

24 lbs. of air are required for each pound of coal consumed.

The rules for firegrate and heating surfaces for the class of steam boilers that are used for such purposes as estate work are obtainable by the following:—

Areas of firegrates and horse-power (nominal) obtainable.

$$G = \text{grate in square feet,}$$
$$P = \text{nominal horse-power,}$$
$$H = \text{heating surface in square yards.}$$
$$P = \sqrt{H \times 9}$$
$$H = \frac{P^2}{G}$$
$$G = \frac{P^2}{H}$$

or per nominal horse-power a boiler requires,

1 square yard of heating surface,
1 ,, foot of firegrate ,,
1 cubic ,, water per hour,
1 ,, yard of steam capacity.

For cylindrical double-flued boilers the length and diameter divided by 6 is very nearly the nominal horse-power.

Proportions for Tubular Boilers.

Each nominal horse-power for tubular boilers requires—

1 foot cube of water per hour,
10 square feet heating surface,
½ „ „ firegrate „
10 square inches sectional area of tube,
13 „ „ flue area,
6 „ „ chimney area,
2 cubic feet steam room,
8 „ „ total boiler capacity.
Tubes to be $\frac{1}{30}$ of their length in diameter.

Cornish or Lancashire Boilers.

Thickness of fire bars ½ to ¾ inch,
Width between „ ⅜ to ½ „
Inclination of „ 1 in 12,
Minimum height of water over flue, 4 inches.
Average „ „ „ 9 „

Inclination of cylindrical boilers (when setting) towards blow-off cock, ½ inch in 10 feet.

DIMENSIONS OF CYLINDRICAL BOILERS.

Nominal Horse-power	Length of Boiler	Diameter	Diameter of Flues	No. of Flues
	ft. in.	ft. in.	ft. in.	
1	6 0	1 9	—	—
2	7 6	2 0	—	—
3	9 0	2 6	—	—
4	10 0	2 9	—	—
5	11 0	3 0	—	—
10	16 0	4 6	2 0	1
15	18 0	5 3	2 4	1
20	20 0	6 0	1 9	2
25	25 0	6 0	1 9	2
30	28 0	6 6	2 0	2
35	30 0	7 0	2 3	2

The 'duty' of an engine means the number of pounds weight lifted 1 foot high by a bushel of Welsh steam-coal, or 94 lbs. weight of coal.

If C = lbs. of coal consumed per indicated horse-power per hour,
and D = 'duty' of the engine in millions of lbs.,

$$D = \frac{186\cdot12}{C}$$

The weight of different classes of coal, and space occupied per ton in storing, are :—

COAL STORE TABLE.

Coal	Weight per Cubic Foot	Space required per Ton
	lbs.	Cubic feet
Welsh anthracite	58·25	33
„ bituminous	53·00	43
Lancashire	50·00	44
Newcastle	50·25	45
Scotch	53·00	43

From the foregoing the general details necessary to lay out a boiler room or decide on the size and power of the boilers may be ascertained. The type of boiler depends entirely on the work required of it. In general an 8 horse-power horizontal engine (portable) is the most useful, but in dealing with boilers only and fixed machinery, it is advisable to have the boiler portable if the engine is fixed. Of this type a 10 horse-power (nominal) vertical boiler, standing 9 ft. 6 in. high by 4 ft. 3 in. diameter, containing three cross tubes 9 in. diameter, weighing 47 cwt., is made by Messrs. Nicholson, of Newark, which has proved in a long experience

to be the most economical for farm machinery that is fixed, or for general use to drive machinery when required—*i.e.* when continuous daily work is not done and the boiler may be called upon to get up steam at short notice.

Of horizontal boilers there are many types, and as their setting in brickwork requires experience, with a view to the boiler being accessible for inspection, it is desirable to have the opinion of an engineer.

Proving Boilers: Cold Hydraulic Test.—To prove the strength of boilers the boiler is first filled with cold water, allowing all the air to escape; when full, all escape is shut off and the proof pump worked until the steam gauge reads *twice* the working pressure at which the boiler is worked; if any leakage is observed or the pressure cannot be got up, or if when got up it slowly goes back, the boiler is defective, and must not be worked until the defect is found out and remedied.

Proving the Steam Gauge.—Steam gauges are often unreliable. There are three types—the Bourdon gauge, that constructed by Schaffer and Budenberg, and the well-known locomotive engine gauge of Smith, of Nottingham, used by the London and North-Western Railway.

The gauge is proved by a mercury column at each pound of pressure to see that the dial records the *true* pressure. Thus 15 lbs. per square inch pressure is the weight of 32 inches of mercury roughly. When 32 inches pressure of mercury are let into the gauge-pipe, the needle of the gauge should read 15 lbs. pressure,

and so on. The gauge may be roughly but practically tested against the water column of the fire hydrant main; in this case, as water is only $\frac{1}{12}$th the weight of mercury, the column of water to be used must be 32 *feet*, not 32 *inches*, or 12 times as heavy, to get a reading of 15 lbs. pressure per square inch. Reference to Chapter IX. will show a table of relative pressures worked out for water and mercury columns.

Gauge Glasses.—Of these every boiler should have one as a mounting, and trial cocks also; but great care is necessary in fitting in the gauge-glass not to pinch it too tight by screwing up the washers that hold the packing too tightly, or the glass will probably break again. De La Bastie's patent toughened glass has not been found any more durable than the ordinary glass. Six spare glasses should always be kept, and broken glasses should be replaced at once; gauging from the trial cocks is most undesirable if it can be avoided.

Injectors and Pumps.—Of injectors as auxiliaries to pumps nothing need be said. Giffard's injector gives the following results:—

Q = gallon of water injected per hour.
P = steam pressure divided by 15.
D = diameter of throat of injector in inches.

$$D = \cdot 0158 \sqrt{\frac{Q}{\sqrt{P}}} \qquad Q = (63 \cdot 4\ D)^2 \sqrt{P}$$

For stationary boilers an injector is desirable as an auxiliary to the pump.

The pump should be of the 'continuous feed' type. In saw-mills it will be desirable, if water is at hand, to arrange a simple and effective fire service by fixing a No. 1 Shand & Mason's patent fixed fire-pump. These pumps are so made that, with a banked boiler fire *and only 5 lbs. of steam*, they will work. For factories they are invaluable.

Sawdust with either damp or oil dropping on it is liable to spontaneous combustion, and in wood-working machinery the liability to fire is very considerable, the rates of insurance being proportionately high unless some extra precaution such as I recommend is observed. If machinery is worth erecting on an estate it is worth protecting, and the extraordinary want of precaution against fire in saw-mills that the writer's experience has shown him to exist on estates generally, where steam power is at hand, makes the rate of fire insurance for such buildings easily intelligible. When the mill is not at work, the sawdust, &c., should be cleared out of the building. The seasoning yard should also be clear of the machinery house.

Safety Valves.—Firstly, let it be understood that lever safety valves sometimes stick, certainly not to the extent that the Admiralty would have us believe was the case on board H.M.S. 'Thunderer' on the occasion of the terrible explosion of one of her boilers; but nevertheless one of the levers *must* be occasionally lifted to release the valve and allow it to blow off. Every estate boiler should have a lock-up valve set at a maximum working pressure in addition to the ordinary lever valve.

The area of safety valves and firegrates is—

$$A = \text{firegrate area.}$$
$$S = \text{safety valve area.}$$
$$S = \cdot 006\ A,$$

or ·8 inch per nominal horse-power.

The principle and proportions of the safety valves known as lever valves is shown in Fig. 27, and the following details—where D = diameter of valve in inches, A = its area, W = the weight in lbs., P, the pressure in lbs. per square inch on the safety valve, is—

$$P = \frac{W\,L}{A\,C}$$

The proportions l = D, and L = D A give 1 lb. per square inch for each 1 lb. at the end of the lever. Then—

G = distance of centre of gravity of lever from fulcrum.

W = weight of lever.

X = weight of valve.

$\frac{G\,W}{L\,A}$ = pressure per square inch due to weight of lever.

$\frac{X}{A}$ = pressure per square inch due to weight of valve.

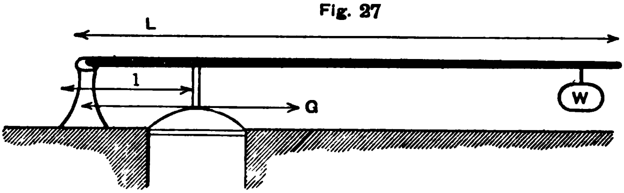
The mitre of safety valves should not exceed $\frac{1}{16}$ inch in width.

For estate purposes Turnbull's patent safety valve the writer has found most suitable.

*N

Feed Water and Fuel.—It will be found that by placing a few sawn oak slabs or refuse into the feed well, sufficient chemical action takes place to keep the

Fig. 27



boiler from furring. The higher the temperature of the feed water the greater the saving in fuel; the feed water can be heated by a feed-water heater, by which 10 to 15 per cent. of fuel may be saved. The quality of the water is of importance; if too hard, it should be softened by Clarke's process (*see* Chap. VIII.), or the boiler will soon deteriorate. Rain water should be turned into the feed tank whenever possible.

Fuel is regulated as regards its nature to the locality; boilers can be easily constructed to burn wood or peat; but for economical generation of steam the Welsh steam coal, such as that supplied from the Harris Navigation Steam Coal Co.'s deep pit at Quaker's Yard is the best. Opportunity has afforded me the means of pronouncing this coal to be quite the best for the above purpose, 13 cwt. of it being found equal to 20 cwt. of the Barnsley coal in the generation of steam to drive two sets of duplex pumps. All Welsh coal requires is gentle raising from below with the pricker, not stirring up. It should become a white hot mass in the fire; it is nearly, if not entirely, smokeless. The fire bars should

not be set too close, and kept well free of clinker, but if properly used such should not become formed.

Incrustation.—The remedy for this is frequent blowing off. Two ounces of sal ammoniac thrown into the feed tank twice a week will prevent scaling becoming mischievous. Oak planks in the supply tank to the feed tank are also effectual.

Inspection and Insurance.—The boiler should be insured in some such reliable office as the Manchester Steam Users' Association.[1] The effect of this will be to ensure regular inspection by competent boiler inspectors and payment in the event of explosion. But insurance does not relieve the stoker or owner from liability, whether civil or criminal. Those employed about boilers or machinery should of course be insured in the Employers' Liability Association, so as to secure the owner.

The stoker of a boiler when in steam should not be called off to help at other work. A steam gauge should be fixed in the engine-room as well as on the boiler.

The Boiler Explosions Act requires a report of accidents involving loss of life or injury to be forwarded within 24 hours to the Board of Trade, Whitehall, under penalty for neglect. This applies to all boilers of every description on land within the United Kingdom.

Steam Scalds.

When steam is used, those that use it should know what to do in case of scalds; they are especially likely

[1] See Appendix.

to occur with bursting of gauge glasses. If the glass has inflicted a cut it will be easy to tell if the glass is left in by gently feeling round the cut; a smart prick shows the glass to be still there, and the wound should be left open for the doctor to deal with. A plug of cotton wool put on the wound will soon stop its bleeding unless a vein or artery has been cut, when pressure should be applied on the blood-vessel by putting a flat pebble on the vessel and securing it tightly with a bandage; or an indiarubber tourniquet may be applied.

Inhalation of hot steam will scald the larynx, and is very dangerous. If it has been inhaled the person should go home *at once* with a cotton-wool pad held to his mouth, and be kept in a temperature of not less than 68° F., till the sore throat, that is sure to follow, has entirely gone. He should speak to no one, which is impossible unless some one goes with him to explain how it occurred.

Scalds on the body should be treated with *engine* oil, *not mineral oil*, and excluded from the air with pads of cotton wool well soaked in oil, as quickly as possible.

Oil is to be poured into the eyes if the steam has gone anywhere near the lids.

Neither in burns nor scalds are the clothes to be removed except the outer ones, and then only if they are wet; they must be gently cut off with scissors. In a very bad case of scalding endeavour always to convey the sufferer so that he rests if possible on a sound place. He should be laid in a blanket with his legs resting on pads of oiled wool, and the same sort

of pad placed wherever a scalded place will touch. He should be entirely covered, before starting, with a blanket. Once a burn or scald is covered from the air it should be, if possible, hardly exposed 10 seconds when re-dressed. This must be impressed on the minds of all if the man is at his own home, otherwise his family *will look* at the wound instead of *dressing* it. The new dressing should go on bit by bit as the old one comes off, the whole object being to try not to expose the wound at all to the air.

Sanitas oil is highly desirable in dressing burns that are deep. The writer has found it keep the wounds sweet, and in hot climates flies do not collect.

CHAPTER XIX.

STEAM POWER AND ENGINES.

On Steam Power and Agricultural Steam Engines—On Portable, Locomotive, and Steam Ploughing Engines and Ropes—On Fowler's Systems and the Compound Principle in Traction and other Engines used in Steam Ploughing.

ONE horse-power is 33,000lbs. lifted one foot high in one minute of time.

The indicated horse-power of an engine is as follows:—

A = area of piston in square inches.
P = average steam pressure in cylinder in lbs. per square inch.
S = length of stroke in feet.
R = number of revolutions per minute.
r = " " second.

The indicated horse-power is—

$$\frac{2\,\text{APRS}}{33{,}0000}$$
$$= \frac{2\,\text{AP}r\text{S}}{550}$$

One British horse-power = 1·0139 French horse-power, or 4,500 kilogrammètres per minute.

The proportion of speed obtainable by pulleys driven by belting is $v = \frac{V \times D}{d}$ where V is the velocity of the driving pulley; v = that of the pulley driven; D is the diameter of the former, and d that of the latter.

Long belts are preferable to short ones.

In general an 8 horse-power portable engine is sufficient for all practical purposes on an estate; as already explained, a small vertical engine and boiler of the overhead crank type is perhaps best for interior work in a farm or cheese factory or dairy works.

The engines, therefore, we have to consider are the portable type and the traction and steam plough engines of recent manufacture.

Of the portable type, although made up to 12 horse-power, nevertheless 8 horse-power is sufficient. Every description of this type is manufactured in England; indeed, there is not a country in the world where agriculture is practised as something more than a livelihood where English portable engines may not be seen. Of this type that manufactured by Messrs. Nicholson has one or two points worthy of attention. In these engines the crank shaft and cylinder are mounted on brackets, and these brackets form a permanent piece of the boiler as regards construction; none of the fixing bolts pass through the shell of the boiler, thus the boiler is left free to expand, and, the strains to the motion of the engine being avoided, the friction on the connecting rod brasses is reduced to a minimum. Another point is that the engine and boiler can be easily dismounted and set up on brick

work as a stationary engine. The useful sizes and comparative cost are as follows:—

Diameter of Cylinder	Stroke in Inches	Speed	Fly-wheel	Cost
Inches			Ft. in.	£
5½	8	175	3 6	108
7	10	150	4 3	154
8½	12	125	4 6	186
9½	12	125	5 0	218

These engines will burn very inferior fuel, such as wood, cotton refuse, or maize stalks.

When using an engine of this type to drive a circular saw it is important to sprag the wheels well, to prevent the engine acquiring a rocking motion in unison with the stroke. It is also advisable to open the blow-off cock at the end of the day's work with a few pounds of steam pressure, so as thoroughly to clear out all sediment from the boiler.

The remaining type of engine we have to consider is the locomotive or traction engine, and the steam ploughing engine with its ropes and gear.

This introduces the subject of compound engines. Steam, when admitted into a cylinder, effects its work by its expansion: at the end of the stroke, that steam is cut off and escapes by the exhaust pipe, having done its work; but it still possesses a considerable degree of expansion, as may be recognised by its noise escaping. A simple engine may be and should be provided with variable expansion gear, by which the 'cut off' of the steam may be secured at any desired point, the piston thus being made to travel with only one-half to

one-third the original volume of steam the whole length of the stroke. The expansion of the steam effects the rest; thus in Fig. 28—

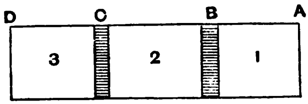


Fig. 28

A B C D represent the steam cylinder with the piston head at each part of the stroke. Steam is admitted at A, the piston travels to C when the steam is cut off, it runs the distance C D—that is, working simply. Now, if we alter the length of the slide valve eccentric rod so as to alter the proportions A B C D and cut the steam off when the piston arrives at B, trusting to the natural expansive force of the admitted steam in A B to drive it to C, then in the first case we use two-thirds of the cubic contents of the cylinder in steam per stroke, and in this latter case only one-third. This arrangement to regulate the length of the slide-valve rod is effected by what is called a '*link motion*,' and may be well adapted with *reversing gear*, to reverse the motion of the engine and to regulate the '*point of cut-off*' as explained. An engine thus constructed is called an engine working expansively, or an engine with variable expansion gear. It is an essential point in economy that portable engines should be so constructed. When the work is heavy, the cut-off should not take place so soon as it may when it is light.

Passing on from the *expansive* principle above

described we come to the steam engine in its perfected state—viz. the *compound engine.*

Here the same principle of expansion is adhered to, but the whole high pressure work of the steam is first secured in the high pressure cylinder; it then exhausts into the low pressure cylinder, and is there stripped of its remaining energy, finally exhausting from this latter cylinder at a reduced pressure of only 8 to 10lbs. per square inch; thus, instead of frightening horses, as single engines often do by the noise of their exhaust, a great economy is effected, and a silent exhaust is secured in using a compound engine. Thus for traction or locomotive purposes or steam ploughing a compound engine is the engine to use. Mr. F. Webb, C.E., of the Crewe Locomotive Works, has applied the compound principle to railway locomotives with a saving of from 15 to 20 per cent. of fuel, and the fact that such engines as the 'Economist,' 'Compound,' and 'Experiment,' on the L. & N.-W. Railway have performed the Irish and Limited Mail train services shows that the compound principle is not incompatible with high and continuously maintained speeds. But in agricultural locomotives the economy secured and the comparatively silent exhaust is of the greatest importance, as coal and water can only be carried to a limited extent, and the public objection and antipathy to traction engines is their noise.[1]

[1] See Highways and Locomotive Act and Bye-laws at the office of the Clerk of the Peace for the County before using the engine.

COMPOUND TRACTION ENGINE FOR GENERAL PURPOSES.

The most useful traction engine for farmers' work and general estate work, where a locomotive is desirable, is the above, which is the manufacture of Messrs. John Fowler & Co., Leeds, who have been the pioneers and introducers of the compounded principle in agricultural locomotives.

The following tables give the details of both the simple and compound locomotive engine for general and for road work. Waggons holding from four to six tons each vary from 60*l.* to 90*l.* each.

The compound engine saves 30 per cent. in fuel and water compared with the simple engine; thus it will travel one-third greater distance for the same quantity of water—a very important point.

In the compound engine will be seen a small valve that opens a direct passage between the steam chests of the two cylinders. This is an independent valve to that of the starting lever, and closes itself by the steam pressure at the back when the engine-driver releases his hold of it. This valve is used to start the engine in any position of the crank. The exhaust is about 8lbs. pressure and almost noiseless. The writer has had many occasions of testing the work of these engines, and they certainly combine efficiency and economy with simplicity, and with ordinary care should last a very long time. The general engine is most useful in clearing woods and sawing timber. Its employment is regulated by the demand for such

SINGLE CYLINDER TRACTION ENGINES. (*John Fowler & Co., Leeds.*)

	General Purpose Engine, fitted with Water Lift, Winding Drum and Rope				Special Road Locomotive, fitted with Water Lift, Winding Drum and Rope, and Injector			
	Class D	Class A	Class B	Class C	Class D	Class A	Class B	Class C
Actual horse-power	14	22	30	38	14	22	30	38
Diameter of driving wheels	5ft.	5ft. 6in.	6ft.	6ft. 6in.	5ft. 6in.	6ft. 6in.	7ft.	7ft.
Width of driving wheels	10in.	14in.	16in.	18in.	10in.	14in.	16in.	18in.
Diameter of fly-wheel	3ft. 6in.	4ft. 6in.	4ft. 6in.	5ft.	3ft. 6in.	4ft. 6in.	4ft. 6in.	5ft.
Width of fly-wheel	5in.	6in.	6in.	7in.	5in.	6in.	6in.	7in.
Revolutions per minute	200	150	150	150	200	150	150	150
Working pressure per sq. inch	120	120	120	120	120	120	120	120
Price	£310	£370	£425	£485	£400	£450	£510	£580

COMPOUND TRACTION ENGINES. (*John Fowler & Co., Leeds.*)

	General Purpose Engine, fitted with Water Lift, Winding Drum and Rope			Special Road Locomotive, fitted with Water Lift, Winding Drum and Rope, and Injector			
	Class A	Class B	Class C	Class D	Class A	Class B	Class C
Actual horse-power	24	33	42	16	24	33	42
Diameter of driving wheels	5ft. 6in.	6ft.	6ft. 6in.	5ft. 6in.	6ft 6in.	7ft.	7ft.
Width of driving wheels	14in.	16in.	18in.	10in.	14in.	16in.	18in.
Diameter of fly-wheel	4ft. 6in.	4ft. 6in.	5ft.	3ft. 6in.	4ft. 6in.	4ft. 6in.	5ft.
Width of fly-wheel	6in.	6in.	7in.	5in.	6in.	6in.	7in.
Revolutions per minute	150	150	150	100	150	150	150
Working pressure per sq. inch	140lbs.	140lbs.	140lbs.	140lbs.	140lbs.	140lbs.	140lbs.
Price	£430	£505	£585	£440	£510	£590	£680

EXTRAS.

	Class D	Class A	Class B	Class C
Crane and gear . .	£30	£50	£75	—
Spring	—	—	—	—
Injector and fittings .	10	10	10	£10
Spark arresters . .	4	4	4	4
Enlarged fire-box . .	8	10	12	15
Packing for shipment .	6	8	10	12

NOTE.—Each engine is fitted with winding forward drum, and 50 yards of rope.

power, and the agent will bear in mind that he should let his engine out on hire when he has no work at home, but always in charge of his own men. It is to be noted that Messrs. Fowler's boilers are of steel, not iron; the horse-power is the *actual* effect, not the nominal horse-power.

Steam Ploughing Engines and Tackle.—Of these there are two systems in use one is the *single engine system* with double drum, the other the *double engine system* with single drums. The former is applicable for a private owner on a medium scale, the latter as a system for hire or for reclamation on a large scale.

The single-engine system pulls the plough across the field with one drum and back with the other; in the double-engine system the plough is worked to and fro by each engine alternately, one being on each headland; they thus can move on without delay into the next field. Thirty to even 50 acres can be ploughed in a day by the single-engine tackle, and a most ingenious arrangement of anchor is now constructed by Messrs. Fowler that moves along the headland as required.

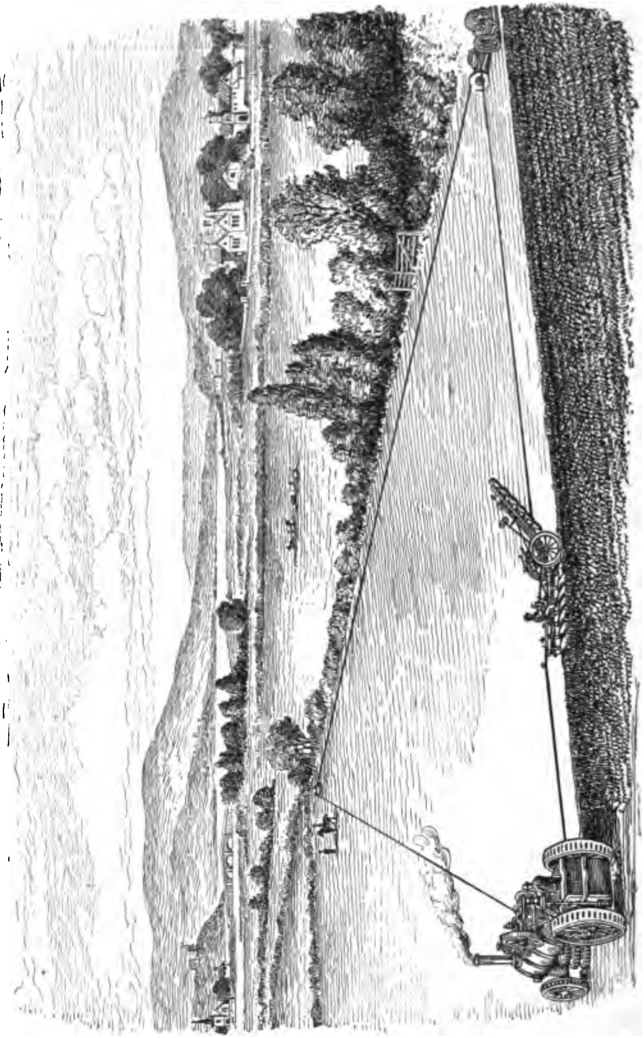


Fig. 29.

The accompanying figure shows the whole system better than any explanation. Experience in the Colonies showed the writer how admirably both systems worked.

The Double-engine System.—The result of the reclamation experiments on the Duke of Sutherland's property at Kildonan with this system on the Kilbrace farm showed that reclamations could be effected for 30*l.* per acre; but with the experience gained there it might be very much less expensive in future operations of the sort. The land was trenched 2½ feet deep for 4*l.* per acre, whereas the cost by hand is stated to approach 20*l.* per acre. The compounded principle is of course applied to these engines.

Wire Rope.—Hard steel wire rope of the very best quality is everything in steam cultivation. It is supplied in the following lengths:—

				£	s.	d.	
For 20 horse-power tackle	36 wires	cost		8	10	0	per 100 yards
„ 16–14 „ „	30 „	„		7	0	0	„
„ 12–10 „ „	24 „	„		5	10	0	„
„ 6 „ „	20 „	„		4	10	0	„
„ windlass tackle	20 „	„		4	10	0	„

Cost of Plant.

A double-engine set complete, ready to work, costs from 1,270*l.* to 2,270*l.* for 20 horse-power tackle for reclamation work, &c.

A single engine set costs about 800*l.*

A small double-engine set, suitable for an estate, is also supplied at an approximate cost of 800*l.*

These are from particulars kindly furnished me by Messrs. John Fowler in August 1884, and it will be at once seen that a distinct advance has been made by them, by bringing such plant within the wants and means of those who wish to avail themselves of steam power either for the purposes of traction or agricultural cultivation.

The reclamation of moor land when the soil is calcareous (*refer to* Chapter XIV.) is now a practicable operation. If the soil is silicious the results will probably be disappointing. But the writer cannot admit the present extraordinary interference with contract to be the means of stimulating such agricultural enterprise. The whole future benefit of a reclaimed soil is the sole property of the owner who reclaims it, but legislation of that mischievous type that believes the farmer to be unable to make his own bargain with his landlord provides that the subsequent cultivator shall be compensated for *his* improvements. It is urged that the farmer, by thus securing his capital, carries on the good work of improvement. My practical experience is that he does nothing of the sort, and leaves the farm in a few years so foul that it has to be steam cultivated. Therefore, reclamation should be looked upon solely as an owner's risk and benefit—*i.e.* reclaimed farms should be held for at least ten years by the owner.

For engines working expansively the following tables are of use as instances of the explanations of each type of engine offered:—

TABLE OF STEAM USED EXPANSIVELY.

Initial Pressure, lbs. per sq. in.	Average Pressure of Steam in lbs. per square inch for the whole Stroke					
	Portion of Stroke at which Steam is cut off					
	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
5	4·8	4·6	4·2	3·7	3·0	1·9
10	9·6	9·2	8·4	7·4	5·9	3·8
15	14·5	13·8	12·7	11·2	8·9	5·8
20	19·3	18·4	16·9	14·8	11·9	7·7
25	24·1	22·9	21·1	18·6	14·9	9·6
30	29·0	27·5	25·4	22·3	17·9	11·5
35	33·8	32·1	29·6	26·0	20·8	13·5
40	38·6	36·7	33·8	29·7	23·8	15·4
45	43·4	41·3	38·1	33·5	26·8	17·3
50	48·3	45·9	42·3	37·2	29·8	19·2
60	57·9	55·1	50·7	44·6	35·7	23·1
70	67·6	64·3	59·2	52·1	41·7	26·9
80	77·3	73·5	67·7	59·5	47·7	30·8
90	86·9	82·7	76·1	66·9	53·6	34·6
100	96·6	91·9	84·6	74·4	59·6	38·5
110	106·2	101·1	93·1	81·8	65·6	42·3
120	115·9	110·3	101·5	89·3	71·5	46·2
130	125·6	119·4	110·0	96·7	77·5	50·0
140	135·2	128·6	118·5	104·1	83·4	53·9
150	144·9	137·8	126·9	111·6	89·4	57·7
160	154·6	147·0	135·4	119·0	95·4	61·6
180	173·9	165·4	152·3	133·9	107·3	69·3
200	193·2	183·8	169·2	148·8	119·2	77·0

TERMINAL PRESSURE.

Rule for Finding the Pressure at the End of the Stroke, or at any Point during Expansion.

P = initial pressure of steam in lbs. per square inch, including the pressure of the atmosphere.

l = distance travelled by the piston before steam is cut off.

L = distance travelled by the piston when the pressure of the steam = X.

X = Pressure of steam in the cylinder, including the pressure of the atmosphere, when the piston has travelled a distance L.

$$X = \frac{P\,l}{L}.$$

The pressure of the atmosphere is to be included in calculating

the expansion; it must therefore be deducted from the results in high-pressure engines. In condensing engines a deduction must be made for imperfect vacuum; this will amount to about 2½ lbs. per square inch in well-proportioned engines.

Expansion of Compound Engines.

A = area of the large cylinder.
a = " small "
L = length of stroke.
l = distance travelled by piston before steam is cut off in small cylinder.

E = rate of expansion $= \frac{A\,L}{a\,l}$.

The mean pressure of steam in lbs. per square inch may be taken as if it acted upon the large cylinder only, and the steam were cut off at $\frac{1}{E}$th of the stroke.

The best proportion of a to A $= \frac{a}{A}\sqrt{E}$, or $a = \frac{A}{\sqrt{E}}$.

Best Proportion of Capacity of Cylinders and Point for Cutting off Steam.

No. of times Steam is to be expanded	Best Point for cutting off Steam	Relative Capacity of Small to Large Cylinder
4	·50L	·50A
5	·45L	·45A
6	·41L	·41A
7	·38L	·38A
8	·35L	·35A
10	·32L	·32A
12	·29L	·29A

CHAPTER XX.

PUMPS AND PUMPING MACHINERY.

On Pumps, Steam and Mechanical—On the Pulsometer Steam Pump—The Principle of the Siphon, and on the Transmission of Power by Compressed Air.

THE principle on which all pumps work is the creation of a vacuum in the pump barrel, when the water enters to fill the vacuum produced. Such a pump is termed a plain lift or suction pump.[1] The pressure of the atmosphere, taken roughly at 15 lbs. per square inch, is sufficient to maintain a column of water to 30 feet; thus the limit of the working power of a pump of this description is 30 feet in depth. It will raise water from a depth of 30 feet and no more.

The contents of any pump are as follows:—

D = diameter of pump barrel in inches
S = stroke of pump in inches
$D^2S \times \cdot 7854$ = cubic inches per stroke.
$D^2S \times \cdot 002833$ = gallons „
$D^2S \times .0004545$ = cubic feet „
$D^2S \times \cdot 02833$ = lbs. of fresh water per stroke.

When the depth exceeds 30 feet a compound pump,

[1] For tube wells and pump, see Appendix.

or 'lift and force pump' as it is called, must be used.

Here the down stroke of the suction cylinder piston expels the water into the forcing cylinder; thus, each time the suction chamber empties, it forces the water up the rising main. If this is effected in one cylinder, by double arrangement of valves, then the pump is called a double-acting lift and force pump.

In machine pumps it is most essential that they should be mounted on a strong iron or light steel frame. This frame should be all in one piece. Secondly, the suction pipe should always be provided with a foot valve; and lastly, the pump valves should be accessible and of gun-metal.

When the pumps are placed in the well at any depth, they should be mounted on a secure iron bracket staging, with an iron ladder leading down to them. This stage should have a coaming all round it, so that if nuts come unscrewed, they may not fall off the stage into the water, and there should be spare space on the stage for a man to disconnect the whole pump easily.

An improved double-barrel force pump, in use very largely on the Great Indian Peninsular Railway, lifting 20 feet, and delivering 50 feet high with 3½-inch barrels, gave 800 gallons per hour.

The same form of pump with 4-inch barrels gave 1,100 gallons per hour, the loss per 100 gallons pumped being 0·8 per cent. These pumps were sent out by Messrs. Shand and Mason, and cost about 35*l.* each.

With horse gear and 3½-inch barrels (two), 620

gallons per hour can be raised from a well 50 feet deep; with treble 3½-inch barrels the quantity raised is increased to 780 gallons. Heavier gear with 4-inch barrels for a strong horse will yield 1,300 gallons per hour.

Hydraulic Three-throw Pumps.—The power derived from a fall of water to drive a turbine or water wheel may be made by very simple attachments to drive a set of three throw pumps for water supply. At Albury Park, Guildford, a turbine erected by Messrs. Easton and Anderson is engaged to pump, when not driving the laundry machinery, by means of these three-throw pumps.

Steam Pumps.—These are of two classes, rotary and direct acting. Direct-acting pumps have a disagreeable ram action that prohibits their use within buildings For this purpose the duplex steam pump (Easton's patent), should be used. The writer fixed two in Queen Anne's Mansions, St. James's Park, London, to return the hydraulic lift waste water to the tanks on the roof of the building, in place of two 40lb. and 60lb. special pumps that were direct acting and the noise of which could be heard all over the house. The rising main was 4½ inches, 135 feet high; with 40lbs. steam pressure each set of pumps threw 4,960 gallons per hour. Their cost was 290*l.* They cost 9*l.* 10*s.* each in brickwork and cement setting. Of rotary pumps, Appold's centrifugal pump is most commonly employed for pumping out water, &c. It is driven with a belt from a steam engine. The sizes of pipes for all centrifugal pumps of this type are:—

TABLE FOR CENTRIFUGAL PUMPS ONLY.

Gallons per Minute	25	70	150	300	500	1,400
Diameter of suction pipe	2	4	5	6	7	8
Diameter of delivery pipe .	1½	3	4	5	6	7

Powerful steam pumps, such as are used in coal mines and for town water supply, are not required except where professional advice has been obtained; a description, therefore, would be superfluous. The Pulsometer steam pump acts on Savory's principle, and is a direct-acting pump somewhat on the principle of the human heart. It is invaluable for pumping out foundations, limestone quarries, and especially where the water is foul; it may be slung in chains over the water, and one great advantage in its use is the absence of all motive parts and exhaust steam. For pumping out flooded headings in mining operations this latter quality is invaluable. The Pulsometer Engineering Co. let these pumps out for hire. It will deliver to 70 feet, but may be made to deliver into a second pump, if 140 feet of delivery is required. It will pump coal washings or liquid manure.

Hydraulic Rams.—These yield about 30 feet in height for each 1 foot of fall. They are used when a fall of water is available and a wheel not required. They should be well protected from frost. There are occasions when, by maintaining the level of the supply pipe and carrying it some distance, a considerable fall may be secured with a free outlet; the natural

slope of the ground should determine their use in this way. A ram to throw 1,000 gallons per day costs about 60*l*. They are invaluable on a dairy farm.

The working pressure of lead pipes is $\frac{1}{10}$th the bursting strain.

The Transmission of Power by Compressed Air.—When it is required to transmit power from a fixed steam engine to a point at a distance, without the use of belts or shafting, the steam engine may be made to compress the air in an air compressor to a considerable pressure; this pressure is then released in an air engine at the point where the power is required, the only connection between the two engines being the air pipe. This may be the case in quarrying, or in sinking wells, when the Ingersoll air rock-drill may be employed with very great advantage by means of compressed air. 45lbs. per square inch is a sufficient pressure of air to work at. Glycerine will be necessary for lubricating the working parts of the air engine in place of oil. The experiments at the Powell Duffryn Collieries (where 26 air engines are driven from one air compressor) showed about 45 per cent. of useful effect. The velocity of the air in the conducting pipe should not exceed 5 feet per second, or unnecessary friction would be set up. To ensure good results, plenty of receiver room should be allowed, so as to secure a steady flow of air, and not waves or impulses in the conducting pipe. The injection of water in the form of a spray into the air cylinders is of importance. Full particulars are given on this subject in a treatise by the author on 'Colliery Ventilation,' where hauling by air locomotives is also described at length.

Siphon Discharges in place of Pumps for Low-level Drainage.—The effect of the siphon is the same as that of a simple pump. So long as the column of water to be supported does not exceed 30 feet in height, the siphon will work. For low-level outfall drains an arrangement of siphons in rows may be applied, fitted with flap valves to maintain the vacuum, and thus obviate the necessity of using a steam pumping engine. The exhaustion of the siphons may be performed by an ordinary windmill driving an air pump connected with the siphons. Examples of such an arrangement may be seen in the Fen drainage outfalls; and indeed, before any large scheme of drainage of that nature is gone into, a visit to that district or to Holland will repay the trouble. In all low-level drainage it must be constantly borne in mind that the cut or low-level drain must be wide and deep enough to be a *reservoir* as well as a drain. Plenty of margin should be left in calculations to admit of heavy rains being carried off by the land drains into it without raising its height appreciably to endanger the outfalls of the side land drains. The rainfall over the area of the great drain must not be neglected in such works.

CHAPTER XXI.

STEAM AND MANUAL FIRE ENGINES.

On Steam and Manual Fire Engines, with Directions for Use.

As we have already explained, hydrants are only applicable where very great pressures are available. It is the *force* of the water more than its volume that extinguishes fire. It is practically an acknowledged fact that a manual engine is not a protection to a large country house. If the fire breaks out at night men have to be collected to work it, and often the same is the case in the daytime; on the other hand, steam fire-engines are ready to work fifteen minutes after lighting their fires, require no gangs of men to be collected, and are of immense power. It is urged that they are liable to get out of order, that a special man must be kept to look after them, &c.; but a very considerable experience shows such is not the case. In practice it will be found that a steam fire engine will be ready to pump with steam up long before a manual engine can be got to work at a country house, and a steam engine is far more economical. In support of this, at a fire at Beale's Wharf, London Bridge, there were 9 steam fire engines at work from 6 to 11½ hours at a total cost of 5*l*. 18*s*. 3*d*. They threw 1,368,452 gallons of water,

or 6,109 tons. To effect this, 89 manual engines would have been required, with 2,402 men to work them, costing for labour and refreshment 623*l*. Again, at the St. Katharine's Docks, 9 steam engines, throwing for 3 to 10 hours in all a total of 938,481 gallons for a cost of 3*l*. 18*s*. 5*d*., if replaced by manual engines would have required 1,904 men to work them at a cost of 476*l*. The equivalent number of manual engines would have been 41. Then the proportion of cost of steam to manual engines is 1 to 121; or a steamer will pump 251,000 gallons for 20 shillings, whilst for the same sum manual engines will only pump 2,227 gallons. Steam was got up at Preston, in one of Shand and Mason's steam fire engines, to the working pressure of 100lbs. per square inch from cold water in 6 minutes and 35 seconds. I have frequently seen steam got up easily under 15 minutes by men not specially accustomed to the work.

There are many forms of fire engines, but those most commonly used are almost all of Messrs. Shand and Mason's manufacture, both manual and steam; and in the Admiralty and other Government Departments the preference has decidedly leant towards their steam engines, two-thirds of the Metropolitan Fire Brigade steam fire engines being constructed by them.

We therefore give general instructions how to treat manual and steam engines of their construction so as to have both types always ready for use. It is essential that at least three persons should be instructed in the method of getting up steam, which is very simple. Whoever first discovers fire should proceed to the

engine-house, and if he cannot get up steam himself, send for the stoker, or, if an alarm is used, it may be an understood thing that the stoker of the engine proceeds at once to the engine to get ready to commence pumping as soon as he hears the alarm. Of this sort of alarm, by far the best is a guncotton rocket or ship's distress signal. Experiments were carried out by the writer with these rockets, and both by night or by day they may be heard from 5 to 12 miles. The Tonite Company are the manufacturers, in Queen Anne's Gate, London, S.W. Bells are utterly useless as a fire signal in the country; the man engaged in ringing the alarm would be better employed getting up steam in the engine, and as three men are sufficient to work with a steam engine where twelve are required for a manual, the water can be poured on the fire without the *fatal delay* that always occurs with manual engines in the country. It has been reported to the writer, in almost every instance into which he has inquired, that 'if the engine could have been got to work *at once*, the fire might have been extinguished;' and in the present day, those who depend on fire extincteurs and manual engines lean on a broken reed. A long series of trials of chemical extincteurs, carried out by the writer to test their efficiency, showed them to be infinitely inferior to a Brigade hand pump. On three bales of cotton nine extincteurs were utterly powerless against spontaneous combustion in the cotton generated purposely by means of acetic acid. It should be observed that, in dealing with fire in ricks, if only one rick is on fire, due respect should be paid to saving the

others at the expense of that one, by placing blankets or rick cloths kept constantly wet on their exposed sides. One most important point may here be urged. Farm buildings should not be built continuously as regards timber on the roof. Whenever or wherever a partition wall can be made a fire-proof division by making it 18-inch brickwork and terminating all timbers in it, it should be done. For the same reasons wooden spouting is most dangerous to farm buildings in case of fire.

The precautions to be observed in using manual engines and their care are very simple, being as follows:—

Manual Engines.

1. The pistons should be always covered with salad or olive oil, to keep the leather cups moist, and for lubricating the cylinders; the bearings should also be oiled before going to work. The wheels and axles require the same attention as in an ordinary carriage.

2. The tube by which water is drawn into the engine is called the suction pipe, and may be made of leather or india-rubber, with an internal spiral wire to prevent collapse from the external pressure of the atmosphere; to the extremity of this is attached a copper strainer to prevent the admission of any substance that would not escape through the jet pipe. In use this must be screwed up tight.

3. Water is conveyed from the engine to the fire by delivery pipe or hose, which may be made of leather, woven canvas, or india-rubber. To the extremity of

the hose, a copper tube called the branch pipe is attached; and this is again fitted with a short moveable tube called the jet pipe, shaped so as to deliver the water in the most efficient manner upon the fire. The suction and hose pipes are fitted with screw couplings, by which they are attached to the engine and to each other respectively.

4. The leather pipes after being used are to be hung up to drain, and, while partially wet, dubbing is to be laid on with a brush, and this should be done at least four times a year. Canvas and india-rubber pipes merely require keeping clean and dry. The hose and implements should be kept in their respective places in the engine ready for use.[1]

5. When the engine is to be worked, place it as near the supply of water as possible; fix the locking carriage by means of the iron pin provided for that purpose. Screw on lengths of suction pipe to reach into the water with the strainer at the end, all the joints being tightened with the hose wrenches; then screw on lengths of hose to reach the fire, with the branch and jet pipe at the end, which may then be conveyed up or down stairs, or in at the window of a room as occasion requires.

6. Should any obstruction to the water appear in working, the engine should be immediately stopped to allow of the rubbish that may have accumulated round the strainer being cleared away. On returning from a fire it is advisable to pump clean water through the

[1] The fire engine to be kept in a detached building, secure from fire itself.

engine, to remove mud, gravel, stones, &c., that may have been drawn into the works.

The cost of manual engines varies greatly with what appliances are required. Of course, where hydrants exist, the same gauge of hose should be used for all.

The management of a steam fire engine of Shand's construction is practically described for reference in the following, of which a copy or two should always be kept printed on card for pocket reference by those qualified to act as stokers.

Other forms of power engines, such as pumps driven by horse gear, may be used, but in practice the steam fire engine is superior in every way on an estate. It may be found desirable not to go to outside fires off the estate except an annual gratuity is paid to encourage smartness in a private brigade; that is purely a matter of organisation. The writer's rule has been 1*l.* for every country or private house, 10*s.* for every farm placed on the list for service, and all damage to engine or hose to be paid for by the person owning the property saved. This money is distributed as gratuity amongst the brigade annually before Christmas.

It is always to be borne in mind that oily cotton waste, oily paper and rubbish generally is excessively likely to ignite spontaneously, and that the use of poplar wood is desirable as a backing for oak panelling, &c., on account of its fire-resisting qualities. Mineral oil casks should be kept outside the house.

INSTRUCTIONS FOR USING AND KEEPING IN ORDER SHAND, MASON, AND CO.'S PATENT STEAM FIRE ENGINES.

Peculiarities of Boiler.—In order to generate steam rapidly, the water space in the boiler is smaller, and the firegrate larger, than in ordinary steam boilers, requiring greater care and attention in management, so as not to unduly reduce the water level, or increase the steam pressure.

Method of filling Boiler.—Unscrew the plug on the blast cock, and screw on in its place the funnel sent with the engine; when water is being poured in, the upper gauge cock should be opened to allow air to escape. On no account put water in at the safety valve. The boiler may also, if preferred, be filled by a portable fire-pump, the hose of which fits the nozzle of the blow-off cock. This pump is also a useful fire brigade appliance, and can be procured at a small cost.

Level of Water in Boiler.—There are three openings in the guard of gauge glass; the two lower ones should be kept covered by the slide, the water showing half an inch in the highest and longest opening before lighting the fire. For greatest expedition in raising steam, the slide may be raised and the water lowered to the bottom of middle opening; but, immediately on starting the engine, the feed water should be pumped up till it stands at two inches above the bottom of the highest opening in the guard of gauge glass, which is the proper water-line, and at which level it must be maintained.

Glass Tube of Water Gauge.—Should the glass tube of water gauge be broken, the cocks are to be shut and a new tube inserted, even when the engine is at work, the water level being in the meantime ascertained by the gauge cocks.

Boiler Feed Pump, and Use of Sea or Muddy Water.—While the engine is at work, the supply of water is kept up by the feed pump drawing from the pump HEAD or from feed TANK in hose box, or by a flexible suction HOSE from a bucket on the ground; the latter two sources being only used when the engine is pumping foul or salt water, in which case clean water must be supplied by means of buckets or otherwise. A three-way cock, with index plate, is provided for confining the supply to any of these three sources, and regulating the quantity pumped, and, in addition, there is a stop-cock on pipe leading to tank to be closed when suction HOSE is used. By opening the small pet cock, it can always be ascertained whether the feed pump is at work or not. If by any means when pumping from HOSE or TANK the feed-pump valve should hang up, the pump can always be flushed or started by putting pointer on HEAD for a moment. It is not desirable to work from HEAD when the water in main pump is at a higher pressure than steam in boiler, as the supply becomes difficult to regulate.

Injector and Instructions for Use.—The principal use of the injector is to force water into the boiler when the engine is stopped for shifting hose or any other purpose, and the feed pump is consequently not at work; it can also be used when the engine is at work,

should the feed pump be out of order. It draws its supply from the tank in hose box, which is kept full when the engine is at work by means of a pipe from the pump head and ball cock, but by means of buckets or otherwise when the engine is pumping salt or foul water ; in the latter case the small stop cock near the pump head is closed. In using the injector, open in succession and to their full extent the wheel regulator, the water inlet cock at bottom, and the steam cock at top of boiler; the two latter being opened gradually, water will then issue from the overflow pipe until the wheel regulator is moved backward and adjusted to suit the steam pressure in the boiler. The injector is working properly when there is no discharge from the overflow pipe, but should it get heated the wheel regulator must be opened to allow water to pass through it by the overflow pipe, the steam and water inlet cocks being both closed.

Stopping Engine with full Steam.—Should the engine be required to stop with a high pressure of steam, both feed pump and injector should be used to put cold water into the boiler. Before stopping, the centre of the fire should also be pushed aside to leave a space for cold air to rush in and cool the fire-box, and the furnace door should be opened wide. The lever regulating the slide valve on blast pipe within the funnel is used to regulate the power of the blast. When the valve is closed the blast is at greatest power, and when the valve is open the blast is reduced. It is better to use this means to regulate the fire when

working the engine, than to open the fire door, as the latter tends to strain the joints of boiler.

Means for reducing the Intensity of Furnace.—Firstly, open the door; and, secondly, make a large hole in the centre of the fire, and then, if necessary, withdraw the fire.

Engine stopped for some time.—Should it be necessary to keep the engine without working for some time, the injector must be used to force water into the boiler, the surplus steam being got rid of by means of the safety valve, and closing the top of funnel by means of a cap to check the draught.

Lighting Furnace and keeping up Steam.—Cover firegrate with dry wood shavings, then with pieces of dry deal or pine wood, about twelve inches long, one inch wide, and quarter inch thick; strew small pieces of coal over the wood, with shavings on the top. The shavings should be lighted under the grate and in the fire-box at the same time. When the wood is well alight more should be added, which may be in larger pieces, and then coal supplied. Coal, coke, or wood may be used for keeping up steam; the best description of each being used and kept ready for use.

Use of small Blast Pipe.—When steam of 20 lbs. pressure has been obtained, the small cock should be opened to admit a jet of steam into the chimney, and entirely closed at 100 lbs. pressure, when the engine may be started. With care, and after some practice, this pressure may be obtained with great rapidity.

Work to be done when Steam is being raised.—Strap the canvas damping cloths on the two hind

wheels to prevent damage from heat; fill with water and keep them so, by means of a small india-rubber hose, during the working of the engine; oil all the working parts, taking care that none of the oil holes are stopped; raise lever of safety valve to make sure of its being in order; open the small cylinder cocks for the escape of condensed steam, and pour melted tallow into the grease cups on top of cylinders. These cups should be always kept full while standing, so as to be ready for immediate use; they are self-acting, and deliver the grease into the cylinders a drop at each stroke.

Regulating Valve.—The engine is started by opening the valve sufficiently for a moderate speed. In single-cylinder engines it will be necessary to put the crank slightly over the dead centre in the direction in which the engine runs before opening the regulating valve.

Instructions for working Engine.—The engine may be worked at any speed not exceeding 260 revolutions per minute, using one of the larger jets with one line of hose, or the two small ones with two lines; but, with engines of No. 4 size and larger, the full power cannot be made available without two or more lines of hose. Changes of jets and hose can be effected without stopping the engine, by means of the stop-valve on the water outlets. To do this, reduce the speed of engine, and open the stop-valve slightly until the fresh line of hose is filled, when the lever of stop-valve is put quickly over to other side. If there is a short supply of water, the steam regulating valve will require

constant attention, as the engine must be instantly stopped when the water supply is reduced to the top of suction strainer. Use oil on the moving parts, and should any of these become hot from absence of oil, apply water by the small hose and jet, which is used for cooling ashes, and then oil well. Attend to height of water in gauge glass, occasionally opening test cock to ascertain if feed pump is at work. Should anything get under feed-pump valves, rendering its action uncertain, use the injector and unscrew caps to examine and clean valves as soon as possible. The cock on pipe connecting pump head and suction chamber is termed the bye-pass, and is used to regulate the engine when working with a small jet, or through a very long line of hose. Care must be taken that this cock is closed when first drawing water to the pumps.

Safety Valve.—Steam of 160 lbs. is the highest required to work the engine. Should the steam pressure gauge ever indicate a greater pressure, the safety valve must be instantly eased to let the surplus steam escape. It will also be advisable occasionally to press up the lever of safety valve to ensure its being in working order. Steam of 100 lbs. is all that is necessary for general work.

Priming.—Priming, that is, water passing with the steam out of the boiler and through the engine, sometimes takes place: when this is the case, reduce the speed of the engine, and open the small cylinder cocks; if it continues and the water is high in boiler, a momentary opening of the bottom blow-off cock will generally stop it. Priming occurs when the engine is

started suddenly at a high speed after standing some time, but it will cease when the fire has brightened up. It is better to start quietly, increasing the speed as the steam pressure rises.

Keeping Boiler in Order.—After using the engine the water should be blown out of the boiler by means of the cock at the bottom, and with steam of not more than 20 lbs. pressure: the screw plugs should also be occasionally taken out, the interior washed, and all sediment withdrawn. The outside of boiler tubes should be cleaned by means of the brush sent for that purpose, or by a small jet of water.

When exposed to Frost.—In localities where the engine is exposed to the action of frost, all pipes and fittings should, after use, be emptied of water and kept empty.

Engine when not in Use.—The engine should be kept in a dry and well-ventilated building, and cared for as an ordinary steam engine and carriage. For cleaning the engine, the dirt and grease should be first cleaned off with cotton waste, and the bright parts of steel, gun-metal, copper, and brass cleaned and polished with a mixture of brilliantine and oxalic acid. No emery or sand must be used for this purpose. The engine should be occasionally moved round by hand, by means of the ratchet lever or fly-wheel to prevent the pistons getting set; and the spring balance of safety valve should be kept slack, so as not to keep a continuous pressure on the spring. All the articles sent with the engine must be kept in their respective places—water in the boiler, and the fire laid ready for

use. The suction pipes with copper strainer are laid in on the hooks at side of framing; hose pipes kept in coils under the box; copper branch pipes and stoking irons are fixed under hose box, or on back foot-board. In the tool-box in front of the boiler are kept the hose and suction wrenches, nut wrenches, all tools, spare valves for pumps, the two tin cans, one filled with best machinery oil and the other with tallow, &c. Under the driver's seat are carried the jet pipes, spare water-gauge glasses, leather washers for hose and suction pipes, &c.

Hose Pipes.—India-rubber and canvas hose and suction pipes merely require being kept clean and dry. Leather hose and suction pipes require frequent rubbing with animal oil when partially wet, so as to keep them soft and pliable.

General Instructions.—One man is generally sufficient to stoke and work Shand, Mason, and Co.'s steam fire engine, but an engineer and stoker may be provided if considered desirable. The period for lighting the furnace must be calculated from the time necessary to reach the scene of fire, bearing in mind the time that is required to obtain steam of 100 lbs. pressure. When arrived at the fire, the engine must be placed in a convenient position for working near the water; the necessary lengths of suction pipe must then be connected with the strainer at one end (entirely immersed in the water). Great care must be used in keeping the leather washers in the coupling screws, and seeing that they are free from sand or dirt; they must also be screwed up quite tight with the wrenches, to prevent

the admission of air, which would spoil the working of the engine. The necessary hose pipe must then be connected, finishing with the branch pipe in a position where the jet of water will be of most use. If necessary, the branch pipe can be strapped to the staff, to enable the fireman to hold it easily.

PART V.

ELECTRICITY AND GAS.

CHAPTER XXII.

ELECTRICITY AS A SOURCE OF POWER, LIGHT, AND COMMUNICATION.

On Electricity as a Source of Light, Heat, Power, and Communication—Precautions for Lightning Rods.

Electricity may be used as a power or as an illuminating agent. As a power, in its present stage, its applicability rests with the local circumstances under which it is proposed that it should be used. For instance, at Redleaf the writer utilised the fall of a stream of water to convey a current a distance of nearly half a mile for scientific purposes. When a dynamo electric machine is rotated rapidly by hydraulic or steam power an intensely powerful current is generated. It may be used as heat, as light, or transmitted as a current and reproduced as power at the other end of the line wire that conveys it. Considered as heat, we may say that by the interposition of material that does not afford a sufficiently free passage to the current, a large portion of the molecular energy of that current is

engaged trying to overcome the resistance of the material: the result is intense heat. Therefore, unless we wish to utilise this current entirely as heat, care must be taken to afford a sufficiently free passage to it by providing a copper wire of adequate sectional area, and by the insertion of safety plugs. We may utilise the current as light by the '*arc*' or '*incandescent*' methods. In the arc method the current heats two carbon pencils opposite each other; a minute space, regulated to be uniform by means of clockwork between these pencils, is bridged over by the current becoming a centre of radiant energy, the whole producing intense light, especially rich in actinic rays for photographic purposes. It is these actinic rays that are so injurious to the eyes. They may be absorbed by the use of uranium or other non-actinic glass, or by the vapour or solution of iodine. They are strongly chemical in their action, acting as oxydisers or reducing agents.

The incandescent method consists of heating a fine platinum wire or carbon filament, or any other partially conducting material, to a white heat *in vacuo* by the passage of the current. The effect is that the light is less actinic, there being none of the violet rays of the voltaic arc present. The energy consumed is 1 horse power per 30 lamps—that is to say, a fall of water capable of developing 4 horse-power will produce a current on a dynamo electric machine of suitable construction capable of maintaining 120 incandescent lamps in action.

We have now to look at electricity as a *means of*

transmitting power to a distance. As a power its generation in its present stage requires power such as steam, and the loss between the power absorbed to produce the current and the power of the current produced is so considerable that, until some modification in the means employed in production can be found which will lessen very greatly this loss, electricity as a motive power cannot compete with compressed air. In a paper[1] read before the Institution of Mechanical Engineers in 1883, I showed the loss to amount to sometimes as much as 45 per cent. M. Tresca gave details of a reduction of that loss; but in practice, in the particular branch of engineering we have to deal with, this loss of power need not be taken into account if the prime motor is hydraulic power, for which nothing is paid out of pocket.

When the current of the first dynamo machine is conveyed to the coils of the second, the reverse takes place; the current revolves the machine, instead of, as in the first machine, the revolution of the, machine producing a current. Thus steam or other power may be turned into electricity, and that electricity re-converted into power, the medium being the dynamo electric machine.

As at present constructed, dynamo electric machines are either '*closed current*' or '*alternating current*' machines. A closed-current machine gives a current of the same polarity. Of this class are Gramme and Siemens' well-known machines; they are the type to

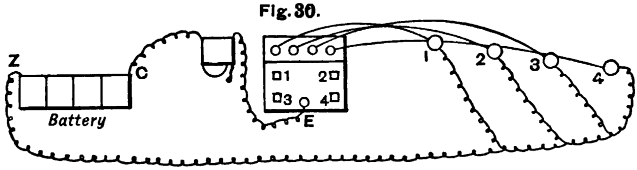
[1] 'Application of Electricity to Coal Mining.' *Transac. Inst. Mech. Engineers*, Liège, 1883, July.

be used for incandescent lighting, and a modification of them for the production and transmission of power. An alternating current machine periodically reverses its electrical polarity. Of this type are the Brush and the arc machines; they are used for arc lighting, are excessively dangerous, and open to much improvement. The conditions under which a man is in danger of his life with the closed-current machines is where he holds or is in contact with one pole of the machine and short circuits the current suddenly through his body by getting another part of his body in contact with apparatus or wires in electrical connection with the other pole.

Arc currents with alternating apparatus may be classed as dangerous to life. Many lives have already been lost with such machines. The question of electric light and power being *sub judice*, further description is useless at the present time.

Electricity as a Means of Communication.—This may consist of ordinary electric bells, electric fire-alarm apparatus, and electric telegraph, or telephone.

Fig. 30.



In electric bell service, the pressure of the button of the bell-push connects a disconnection in the wire, thus completing the circuit between the bell and the battery. Fig. 30 shows the general electric connections. The

rooms 1, 2, 3, 4, are connected each to a numbered line screw on the indicator as regards one wire; the other goes on to the nearest place on the zinc or battery wire. The screw marked E is the 'earth' or general return screw. In the indicators made by Messrs. Apps and Co. the system is always adopted of having test boards to the indicator. It is of the greatest convenience both in erection, testing, or in changing circuits in case of illness in bedrooms. The battery used is the Leclanché battery. Here chloride of ammonia acts upon zinc to make zinc chloride, which is soluble in solution of ammonia. The batteries last one to two years without attention. Each cell is possessed of an electric motive force of two ohms. In the Appendix will be found instructions for working them.

In laying electric wires all joints must be twisted when clean and soldered, then covered with Chatterton's compound. For outside work, No. 16, B.W.G. C.P.R. wire covered to that known as 'Morse' or 'leading in' wire must be used. It is advisable also for battery wires.

Electric Fire Alarms.—The writer introduced some years ago an automatic metallic thermometer that served the purposes of a fire-station call and an automatic circuit closer. It is very largely used at Sion Gardens; it is also used in the frozen meat trade from Australia, and in coal mines.

Electric Telegraph and Telephones.—The single-needle Morse and Wheatstone's A B C electro-magnetic instruments are at present used. The former is electrically the simplest, the latter anyone can read;

but the telephone on the Gower Bell principle will be found the most practical for estate purposes. A No. 11 galvanised iron wire will suffice for the line wire. The 'earth' should be gas or water pipes if possible. The earth connection is on no account to be made on the lightning conductor.

Lightning Conductors.—These, from experience recently gained by the Committee on Lightning Rods from details gathered from all parts of the world, are to be thus erected. The *stranded copper conductor* to be not less than ½-inch diameter, tightly pinned to the building by gun-metal holdfasts (glass insulators are useless). The *point* of the conductor to be 3 ft. 6 in. above the chimney and forked.

The *roof lead* to be in connection with the conductor.

A line of observation at any and all points round the building with a theodolite shall, if laid at 45° from the conductor to the earth, not include any portion of the building.

Machinery, or large bodies or masses of metal, to be in connection with the conductor. The efficacy of the earth connections should be tested by an electrician from time to time. This should, if possible, end in water, and every endeavour should be made to secure good contact and sufficient area and moisture by burying the plate deep enough if water is not available. It is just before heavy storms when the earth is parched that the earth connection is most deficient.

CHAPTER XXIII.

GAS AND ITS WASTE PRODUCTS.

On Gas and its Waste Products.

THERE is no doubt that a large establishment should be lit with gas as regards basement and offices, stables, &c. It is also desirable for a cheese factory or dairy on a large scale, unless the steam power at hand would admit of incandescent lighting by electricity; then the latter is obviously preferable.

The principal features to be noted in the use of gas as an illuminative agent are as follows:—

Each lamp burner consumes 5½ cubic feet per hour.
Each common „ 4½ „

The difference between the summer and winter consumption, affecting as it does the quantities of coal required, is as follows:—

In summer, per month, the average consumption for each lamp is 1,000 to 1,800 cubic feet; in winter it rises to 1,800 to 2,400 cubic feet. Argand or specially large burners consume from 8 to 10 cubic feet per hour.

In carrying along the main, the level obviously

should be an ascending one. Where it exceeds 30 feet in section, a governor is generally introduced to regulate the flow of gas.

Pressure of gas is measured by the water gauge in inches; a table of water-gauge readings is given at the end of the chapter. $\frac{1}{100}$ of an inch in pressure must be added for every foot of rise or deducted for every foot of fall to the initial driving pressure.

This initial pressure should not exceed $2\frac{1}{2}$ inches of water gauge, or there will be a great loss in leakage by excess of pressure.

Retorts.—These produce 2,800 cubic feet of gas per 24 hours, with a charge of $1\frac{1}{2}$ cwt. of suitable coal. One-fourth of the retort capacity should always be added in estimation for repairs. 5 cwt. of fuel will carbonise 1 ton of coal.

GAS PRODUCTS OF COAL.

Produce	Newcastle, per Ton	Cannel Coal, per Ton
Cubic feet of gas . . .	9,500 to 10,000	11,500 to 15,000
Lbs. of coke	1,500 „ 1,540	715 „ 720
Lbs. of coal tar	70 „ 90	710 „ 720
Lbs. of ammoniacal liquor .	80 „ 1,200	none

The fuel required for the retorts being 20lbs. per cwt.

Gas Purifiers.—These are of two kinds, wet and dry. Wet purifiers require 1 bushel of lime with 48 bushels of water to purify 10,000 feet cube of gas. Dry purifiers require 1 superficial foot of area to every 600 cubic feet of gas, and 1 bushel of lime dry to every 10,000 cubic feet of gas purified.

Siphons.—These are U-shaped bends in the pipe to collect water or gas liquor where it would otherwise

collect by gravity; with this in view, a dead level in the main is to be avoided.

SERVICE BRANCHES OFF THE MAIN SUPPLY.

For	2	lights the diameter	of the service	pipe to be	$\frac{1}{4}$	inch
„	6	„	„	„	$\frac{3}{8}$	„
„	12	„	„	„	$\frac{1}{2}$	„
„	25	„	„	„	$\frac{3}{4}$	„
„	50	„	„	„	1	„
„	70	„	„	„	$1\frac{1}{4}$	„
„	120	„	„	„	$1\frac{1}{2}$	„
„	200	„	„	„	2	„

Three-eighths of an inch is the smallest desirable size for gas pipes in practice. Galvanised wrought-iron pipe is the best for service pipes. They should be screwed a good distance, on account of repairs.

No light should be nearer wood-work than 10 inches, or with lath and plaster ceiling it should be 3 feet 6 inches away.

2,200 cubic feet per annum is the average consumption per head of the population in towns.

Derbyshire main coal per ton will yield about 9,400 cubic feet of gas.

The actual cost of gas apparatus for a large farm with extensive buildings would be from 100*l.* to 160*l.*; for a group of cottages or small village, say 200 inhabitants, 500*l.* to 600*l.*

Other systems of gas illumination by means of hydro-carbons have been tried and found successful: of these there are many patents, capable of great improvement.

One man is sufficient to attend to the works of a 200 to 500 light coal-gas apparatus. The gas lime will be found of use for agricultural purposes; it is a

destructive agent for liver-fluke on sheep pastures. The coal tar also is of use, but the ammoniacal liquor is best sold. No gas water or refuse from gasworks may be discharged into any stream. (Rivers Pollution Act.)

TABLES OF THE MAXIMUM SUPPLY OF GAS THROUGH PIPES IN CUBIC FEET PER HOUR, THE SPECIFIC GRAVITY BEING TAKEN = ·45, CALCULATED FROM THE FORMULA

$$Q = 1{,}000\sqrt{\frac{D^5H}{GL}}.\quad \text{(J. T. Hurst.)}$$

Length of pipe = 10 yards.

Diameter of Pipe in inches	Supply of Gas in cube feet per hour									
	Pressure by the Water Gauge in inches									
	·1	·2	·3	·4	·5	·6	·7	·8	·9	1·0
$\frac{3}{8}$	13	18	22	26	29	31	34	36	38	41
$\frac{1}{2}$	26	37	46	53	59	64	70	74	79	83
$\frac{3}{4}$	73	103	126	145	162	187	192	205	218	230
1	149	211	258	298	333	365	394	422	447	471
$1\frac{1}{4}$	260	368	451	521	582	638	689	737	781	823
$1\frac{1}{2}$	411	581	711	821	918	1,006	1,082	1,162	1,232	1,299
2	843	1,192	1,460	1,686	1,886	2,066	2,231	2,385	2,530	2,667

Length of pipe = 100 yards.

Diameter of Pipe in inches	Supply of Gas in cube feet per hour										
	Pressure by the Water Gauge in inches										
	·1	·2	·3	·4	·5	·75	1·0	1·25	1·5	2	2·5
$\frac{1}{2}$	8	12	14	17	19	23	26	29	32	36	42
$\frac{3}{4}$	23	32	42	46	51	63	73	81	89	103	115
1	47	67	82	94	105	129	149	167	183	211	236
$1\frac{1}{4}$	82	116	143	165	184	225	260	291	319	368	412
$1\frac{1}{2}$	130	184	225	260	290	356	411	459	503	581	649
2	267	377	462	533	596	730	843	943	1,033	1,193	1,333
$2\frac{1}{2}$	466	659	807	932	1,042	1,276	1,473	1,647	1,804	2,083	2,329
3	735	1,039	1,270	1,470	1,643	2,012	2,323	2,598	2,846	3,286	3,674
$3\frac{1}{2}$	1,080	1,528	1,871	2,161	2,416	2,958	3,416	3,820	4,184	4,831	5,402
4	1,508	2,133	2,613	3,017	3,373	4,131	4,770	5,333	5,842	6,746	7,542

Length of pipe = 1,000 yards. (J. T. Hurst.)

Diameter of Pipe in inches	Supply of Gas in cube feet per hour — Pressure by the Water Gauge in inches						
	·5	·75	1·0	1·5	2·0	2·5	3·0
1	33	41	47	58	67	75	82
1½	92	113	130	159	184	205	226
2	189	231	267	327	377	422	462
2½	329	403	466	571	659	737	807
3	520	636	735	900	1,039	1,162	1,273
4	1,067	1,306	1,508	1,847	2,133	2,385	2,613
5	1,863	2,282	2,635	3,227	3,727	4,167	4,564
6	2,939	3,600	4,157	5,091	5,879	6,573	7,200

Length of pipe = 5,000 yards.

Diameter of Pipe in inches	Supply of Gas in cube feet per hour — Pressure by the Water Gauge in inches				
	1·0	1·5	2·0	2·5	3·0
2	119	146	169	189	207
3	329	402	465	520	569
4	675	826	955	1,067	1,168
5	1,179	1,443	1,667	1,863	2,041
6	1,859	2,227	2,629	2,939	3,220
7	2,733	3,347	3,865	4,321	4,734
8	3,816	4,674	5,397	6,034	6,610
9	5,123	6,274	7,245	8,100	8,873
10	6,667	8,165	9,428	10,541	11,57
12	10,516	12,880	14,872	16,628	18,25

Dimensions of Mains, with Weight of One Length.

Diameter in ins. .	4	6	8	9	10	14	18	20
Length in feet .	9	9	9	9	9	9	9	9
Thickness in ins.	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$
Weight in cwts. .	1·36	2	3·56	4·06	4·37	7·75	11·75	13·25

Gas as Power.—The power produced by the explosion of gas mixed with air at every third stroke or less in the cylinder of an engine constitutes a gas

engine. Of these, of which there are many types and modifications, that recently manufactured by Messrs. Crossley is the most perfect. It is useful for pumping, sawing firewood, &c., and for driving lathes and domestic purposes. They are used up to 8 horse-power. The same results, though perhaps not quite to such a degree of perfection, have been obtained by the use of hot-air engines.

CHAPTER XXIV.

NOTES ON LIFTING GROWN TREES, ETC.

Note on Lifting Grown Trees, Painting Ironwork, and on the Superannuation of Aged Men.

Occasion frequently arises in railway works where a row of trees require to be set back some distance. It also arises in estate management, but it is not generally understood that not only is such an operation feasible, but it can be performed at comparatively little expense on trees up to thirty feet high. McGlasham's transplanting machine is the one that gave the best results in Paris, where it was used for moving out trees from the Bois de Boulogne to be replanted along the boulevards of the city.

The operation consists of setting the machine on the surface of the soil in such a way that the tree to be lifted stands in the centre. The spades of the machine are then driven down as far as they will go, and pressed outwards whilst driving them. The powerful lifting screws with which the machine is fitted are then gradually set in motion, and the tree with its ball of earth gradually screwed up out of the ground. The whole machine, with the tree so supported, is then drawn to the site where it is to be replanted, and, the

screws being gently released, the tree is gradually and safely lowered into the hole dug for it. It has this great advantage, that the roots of the tree are not exposed by having to dig out the surface soil. The cost of such machines are from 18*l.* to 30*l.* for trees from 15 to 30 feet high. Three men are required to use them. The raising of trees that have been blown down is not advisable, although perhaps the best instance of such a piece of work is that of the very large cedar at Sion Gardens, Brentford, which formed a conspicuous ornament in the frontage of Sion House looking from the river. This tree, having been blown down, was replanted by means of hydraulic jacks and guy ropes, under the superintendence of Mr. Woodbridge, the head gardener to His Grace the Duke of Northumberland, in 1881, and apparently is more firm than before, since it has stood through the memorable gale of December 1883, which stripped half the northern portions of England of some of their finest timber.

In operations of such a nature it is very desirable to use a stranded steel or iron wire rope. The expansion and contraction of hemp ropes with rain and wind are very troublesome, and not a little dangerous in the case of guys.

The best preparation [1] for painting iron rods to support the limbs of trees, and indeed for iron fencing also, is as follows, and has been found very successful on the Midland Railway for fencing switch bars and point rods :—

[1] The writer thinks Spence's metal will prove better than lead caps for decayed limbs.

Coal tar	4 gallons.
Best resin, powdered	¼ lb.
Fresh slaked lime	¼ bushel.

It should be thoroughly boiled and stirred, and applied as hot as possible with a stiff blacking brush by an *energetic* man; the mistake so frequently made being to put such work in the hands of old men. By all means let old men be employed, but not to waste good material. The writer may be excused for advising the formation of a superannuation fund on large estates, for the housing of those unable to earn weekly wages; and with a very little arrangement two cottages may easily be made suitable as a comfortable retreat for them, where with a large garden and a few hives of bees, they can spend the remainder of their days. The point in such an arrangement to be always borne in mind, is that it must be distinctly a *superannuation* scheme presented to them as an advisable *investment*; anything that can savour of charity or almshouses from *their* point of view should be religiously avoided, or the scheme must fail. The writer feels it his duty to comment on the want of such arrangements, and to endeavour to press upon employers of labour that men who can no longer stoop with ease, and to whom every change in the weather brings an extra pain, although they may at times feel the old habit of work give them a fictitious feeling of comparative strength, must be recognised in the fair give and take of life as men who have done their work; if honestly, then let them have their rest. Much of the bitterness of the lower classes towards the upper would never exist if only such con-

siderations for honest work were more often shown. An experience of the worst of the Black Country, of miners, railway men, and agricultural labourers, has shown the writer that the erroneous feeling that a labouring man has had ground into him that every one wishes to use him as a machine, and not as a fellow-creature, is only to be removed by superannuation, and that the greatest good may result from its application on landed estates. It has been known to form the basis of a tie between an engineer and his men that has made his staff and himself able to carry out work at both rates of wages and hours that other men could not be got for.

CHAPTER XXV.

ON THE ESTIMATION OF THE HORSE-POWER OF A WATER-MILL, THE GAUGING OF WEIRS, AND RATIOS OF THEIR SLOPES.

Note on the Horse-power of a Water Mill, the Gauging of Weirs, and the Ratios of their Slopes.

A STREAM 2,000 yards long has a fall of 8 feet. It is required to estimate the power that can be got for a mill from it. Firstly, the quantity of the stream must be got. Take the stream at an average width, say 20 feet; the area is then obtained by plumbing the line across the river in, say, four places; the average depth is thus got; then supposing the average obtained is 3 feet, then 3×20 is the cross sectional area of the stream. The speed has now to be measured at which the current flows. This is done by stretching two measuring tapes across the stream 66 feet, or a chain, apart. A float is then put into the river a few yards above the top tape, and its time traversing down stream the distance marked, *i.e.* 66 feet, is noted accurately. Suppose the observed time to be 20 seconds, then $\frac{66 \times 60}{20}$ or 198 feet per minute. This is the maximum velocity

of the stream. The *mean* velocity is over the whole area 198 × ·84 = 166 feet per minute, the mean velocity of a stream having been shown to be 84 per cent. of the maximum velocity. Then 166 × 60 = the discharge in cubic feet per minute, or 9,960 cubic feet of water per minute is the *total available quantity of water.*

This is now to be estimated in horse-power.

A cubic foot of water weighs 62·3 lbs. A horse-power is 33,000 foot lbs. and a breast wheel yields 50 per cent. of the gross power of the water. Then

$$\frac{9{,}960 \times 62{\cdot}3 \times 8 \text{ feet fall} \times {\cdot}5}{33{,}000} = \text{available horse-power,}$$

or about 76 horse-power.

The discharge in cubic feet per minute, multiplied by the fall in feet at the wheel multiplied by the percentage of the gross power that the class of wheel used yields, multiplied by the weight of 1 cubic foot of water, 62·3 lbs., is to be divided by the one horse-power of 33,000 foot pounds; the result is the horse-power of the stream.

The diameter of the wheel may be twice that of the fall—that is, 16 feet—its speed 240 feet per minute, and the depth of the bucket 1 ft. 6 in.; the width of the wheel would be $\frac{9{,}960}{240 \times 1{\cdot}5}$ = roughly 30 feet. The duty from a good overshot wheel would be 75 to 80 per cent., that of a breast wheel 45 to 60, and that of an undershot wheel, where the impulse of the water is the power, 27 to 30 per cent.

A chip of wood makes the best float for such work,

as the wind does not act on it so easily when it is floating down the stream.

Gauging the Overflow of Weirs.—A complete method with gauges is given at length in Box's 'Hydraulics,' p. 63; but the operation of gauging is one that requires experience and care. The depth of water flowing over, multiplied into its width, gives a fair idea of the comparative quantities passing.

The *slopes of weirs* are of great importance, however small such weirs may be. The delivery of the water over the weir should be effected so as to strike the bed of the river at an oblique angle, and yet at a velocity suitable to the bed of the river and the material of which it may be composed. A long flat slope of 3 to 1, 4 to 1, or even 5 to 1, is best; but if a cascade is required, a slope of 3 to 1 broken up into a series of steps is effective and does no harm. A straight fall of water vertically is very destructive both to the foundation of the weir and the bed of the river, and is always to be avoided.

APPENDIX.

WEIGHTS AND MEASURES.

Avoirdupois Weight.

drachms	ozs.	lbs.	qrs.	cwts.	ton	French grammes
1 =	·0625 =	·0039 =	·000139 =	·000035 =	·00000174 =	1·771846
16 =	1 =	·0625 =	·00223 =	·000558 =	·000028 =	28·34954
256 =	16 =	1 =	·0357 =	·00893 =	·000447 =	453·59
7168 =	448 =	28 =	1 =	·25 =	·0125 =	12,700
28672 =	1792 =	112 =	4 =	1 =	·05 =	50,802
573440 =	35840 =	2240 =	80 =	20 =	1 =	1,016,048

Troy Weight.

grains	dwts.	ozs.	lb.	French grammes
1 =	·04167 =	·00208 =	·0001736 =	·0648
24 =	1 =	·05 =	·004167 =	1·555
480 =	20 =	1 =	·0833 =	31·1035
5760 =	240 =	12 =	1 =	373·242

175 lbs. troy = 144 lbs. avoirdupois.
lbs. avoirdupois × ·82286 = lbs. troy.
lbs. troy ... × 1·2153 = lbs. avoirdupois.

Long Measure.

ins.	feet	yards	fath.	poles	furl.	mile	French mètres
1 =	·083 =	·02778 =	·0139 =	·005 =	·000126 =	·0000158 =	·0254
12 =	1 =	·333 =	·1667 =	·0606 =	·00151 =	·0001894 =	·3048
36 =	3 =	1 =	·5 =	·182 =	·00454 =	·000568 =	·9144
72 =	6 =	2 =	1 =	·364 =	·0091 =	·001136 =	1·8287
198 =	16½ =	5½ =	2¾ =	1 =	·025 =	·003125 =	5·0291
7920 =	660 =	220 =	110 =	40 =	1 =	·125 =	201·16
63360 =	5280 =	1760 =	880 =	320 =	8 =	1 =	1609·315

SURVEYING MEASURE (Lineal).

ins.	links	feet	yards	chains	mile	French mètres
1 =	·126 =	·0833 =	·0278 =	·00126 =	·0000158 =	·0254
7·92 =	1 =	·66 =	·22 =	·01 =	·000125 =	·2012
12 =	1·515 =	1 =	·333 =	·01515 =	·000189 =	·3048
36 =	4·545 =	3 =	1 =	·04545 =	·000568 =	·9144
792 =	100 =	66 =	22 =	1 =	·0125 =	20·116
63360 =	8000 =	5280 =	1760 =	80 =	1 =	1609·315

1 knot or geographical mile = 6082·66 feet = 1854 mètres = 1·152 statute mile.

1 Admiralty knot = 1·1515 mile = 6080 feet.

SQUARE MEASURE.

ins.	feet	yards	perches	roods	acre	square mètres
1 =	·00694 =	·000772 =	·0000255 =	·00000064 =	·000000159 =	·000645
144 =	1 =	·111 =	·00367 =	·0000918 =	·000023 =	·0929
1296 =	9 =	1 =	·0331 =	·000826 =	·0002062 =	·8361
39204 =	272¼ =	30¼ =	1 =	·025 =	·00625 =	25·292
1568160 =	10890 =	1210 =	40 =	1 =	·25 =	1011·7
6272640 =	43560 =	4840 =	160 =	4 =	1 =	4046·7

1 chain wide . = 8 acres per mile.
10 square chains = 1 acre.
1 hectare . . . = 2·471143 acres.

$$1 \text{ square mile} \begin{cases} = 27878400 \text{ sq. feet.} \\ = 3097600 \text{ sq. yards.} \\ = 640 \text{ acres.} \end{cases}$$

Acres × ·0015625 = sq. miles.
Sq. yds. × ·000000323 = sq. miles.

CUBIC MEASURE.

s.	feet	yard	cubic mètre, or stere.
1 =	·0005788 =	·000002144 =	·000016386
1728 =	1 =	·03704 =	·028315
46656 =	27 =	1 =	·764513

Sheet Iron—Weight of a Superficial Foot for Iron Roofs.

B. W. Gauge	Dec. of an inch	Weight in lbs.	B. W. Gauge	Dec. of an inch	Weight in lbs.
00000 (½)	·500	20·208	16 ($\frac{1}{16}$)	·063	2·546
0000	·450	18·187	17	·055	2·223
000	·437	17·662	18	·048	1·940
00 (⅜)	·375	15·156	19	·042	1·697
0	·340	13·742	20	·035	1·415
1	·300	12·125	21	·033	1·334
2	·284	11·477	22	·029	1·712
3	·261	10·549	23	·025	1·011
3—4 (¼)	·250	10·104	24	·022	·892
4	·239	9·660	25	·020	·809
5	·217	8·770	26	·018	·727
6	·208	8·407	27	·016	·646
7	·180	7·275	28	·014	·566
8	·166	6·709	29	·013	·525
9	·148	5·982	30	·012	·485
10	·137	5·537	31	·010	·404
11 (⅛)	·125	5·052	32	·009	·364
12	·109	4·405	33	·008	·323
13	·094	3·799	34	·007	·283
14	·080	3·233	35	.005	·202
15	·072	2·910	36	·004	·162

Pressure of Air, as shown by the Water Gauge.

Height in in.	Pressure in lb. to the sq. ft.	Height in in.	Pressure in lb. to the sq. ft.	Height in in.	Pressure in lb. to the sq. ft.
0·01	0·05	0·19	0·98	0·37	1·92
0·02	0·10	0·20	1·04	0·38	1·97
0·03	0·15	0·21	1·09	0·39	2·02
0·04	0·20	0·22	1·14	0·40	2·08
0·05	0·26	0·23	1·19	0·41	2·13
0·06	0·31	0·24	1·24	0·42	2·18
0·07	0·36	0·25	1·30	0·43	2·23
0·08	0·41	0·26	1·35	0·44	2·28
0·09	0·46	0·27	1·40	0·45	2·34
0·10	0·52	0·28	1·45	0·46	2·39
0·11	0·57	0·29	1·50	0·47	2·44
0·12	0·62	0·30	1·56	0·48	2·49
0·13	0·67	0·31	1·61	0·49	2·54
0·14	0·72	0·32	1·66	0·50	2·60
0·15	0·78	0·33	1·71	0·51	2·65
0·16	0·83	0·34	1·76	0·52	2·70
0·17	0·88	0·35	1·82	0·53	2·75
0·18	0·93	0·36	1·87	0·54	2·80

PRESSURE OF AIR, AS SHOWN BY WATER GAUGE—*continued.*

Height in in.	Pressure in lb. to the sq. ft.	Height in in.	Pressure in lb. to the sq. ft.	Height in in.	Pressure in lb. to the sq. ft.
0·55	2·86	0·67	3·48	0·79	4·10
0·56	2·91	0·68	3·53	0·80	4·16
0·57	2·96	0·69	3·58	0·81	4·21
0·58	3·01	0·70	3·64	0·82	4·26
0·59	3·06	0·71	3·69	0·83	4·31
0·60	3·12	0·72	3·74	0·84	4·36
0·61	3·17	0·73	3·79	0·85	4·42
0·62	3·22	0·74	3·84	0·86	4·47
0·63	3·27	0·75	3·90	0·87	4·52
0·64	3·32	0·76	3·95	0·88	4·57
0·65	3·38	0·77	4·00	0·89	4·62
0·66	3·43	0·78	4·05	0·90	4·68

AIR PRESSURES AND VELOCITIES.

Miles per hour	Lbs. per sq. ft.	Miles per hour	Lbs. per sq. ft.	Miles per hour	Lbs. per sq. ft.	Miles per hour	Lbs. per sq. ft.
1	·005	26	3·380	51	13·005	76	28·880
2	·020	27	3·645	52	13·520	77	29·645
3	·045	28	3·920	53	14·045	78	30·420
4	·080	29	4·205	54	14·580	79	31·205
5	·125	30	4·500	55	15·125	80	32·000
6	·160	31	4·805	56	15·680	81	32·805
7	·245	32	5·140	57	16·245	82	33·620
8	·320	33	5·445	58	16·820	83	34·450
9	·405	34	5·780	59	17·405	84	35·280
10	·500	35	6·125	60	18·000	85	36·125
11	·605	36	6·480	61	18·605	86	36·980
12	·720	37	6·845	62	19·220	87	37·845
13	·845	38	7·220	63	19·845	88	38·720
14	·980	39	7·605	64	20·480	89	39·605
15	1·125	40	8·000	65	21·125	90	40·500
16	1·280	41	8·405	66	21·780	91	41·405
17	1·445	42	8·820	67	22·450	92	42·320
18	1·620	43	9·245	68	23·120	93	43·245
19	1·805	44	9·680	69	23·805	94	44·180
20	2·000	45	10·125	70	24·500	95	45·125
21	2·205	46	10·580	71	25·205	96	46·080
22	2·420	47	11·045	72	25·920	97	47·045
23	2·645	48	11·520	73	26·645	98	48·020
24	2·880	49	12·005	74	27·380	99	49·005
25	3·125	50	12·500	75	28·125	100	50·000

Carburetted hydrogen being taken as ·45 specific gravity where air equals 1·0, these may be readily compared if an air-meter is used for velocities.

Fluxes for Solders for Metals.

Iron or steel	Borax or sal ammoniac.
Copper and brass	Chloride of zinc or sal ammoniac.
Tinned iron	Chloride of zinc or resin.
Zinc	,, ,,
Lead	Tallow or resin.
Lead and tin pipes (speaking tubes)	Resin and sweet oil.

Solders.

For lead . . .	use	tin	1	lead	$1\frac{1}{2}$	parts.	
,, tin . . .	,,	,,	1	,,	2	,,	
,, pewter . . .	,,	,,	2	,,	1	,,	
,, hard brazing .	,,	copper	3	zinc	1	,,	
,, soft brazing . .	,,	tin	1	copper	4	zinc	3 parts.

Iron standards and cramps should be let into stone with melted sulphur 1 to sand 2, not with lead.

Scotch and Irish Measure.

1 English mile . . .	=1,760 yards	=1·00000
1 Scotch ,, . . .	=1,984 ,,	=1·12159
1 Irish ,, . . .	=2,240 ,,	=1·27273
1 Statute acre . . .	=4,840 sq. yards.	=1·00000
1 Scotch ,, . . .	=6,150·4 ,, ,,	=1·27074
1 Irish ,, . . .	=7,840 ,, ,,	=1·61983

Storage of Ice.

112 lbs. of ice requires 6 cubic feet of room to store it.

Non-Conductors.—Felt, sawdust, straw. Ice houses to have double doors.

The comparative facility with which heat is transmitted through different building materials:—

Copper . . .	1,000	Marble . . .	54
Iron	450	Slate	42
Zinc	430	Bath stone . . .	27
Lead . . .	230	Chalk	25

Asphalte	15	Oak	4
Glass	14	Fir	3
Brick	13	Cork	2
Lath and plaster	10	Canvas	1

Cubical Expansion of Air (Air Compressors).

For each degree Fahrenheit	·0020361
„ „ „ Centigrade	·003665

Absolute Zero.

On Fahrenheit's scale	−491·135
„ Centigrade „	−272·9

Expansion of Water.

Water attains its minimum bulk at 39·1° F. From that temperature to freezing point, or 32° F., it expands by cold and is one-twelfth part greater in bulk than it was at 39·1° F.

Main chimney stacks for greenhouses, factories, &c., where all flues from different vineries, &c., are taken into one flue, and the chimney erected in some spot out of sight, except the smoke be consumed at the base of the chimney, the heights are :—

Weight of Coal Burnt per hour	Height of Shaft
100 lbs. or under	60 feet.
500 „ „	100 „
1,000 „ „	120 „
2,000 „ „	140 „
3,000 „ „	160 „
4,000 „ „	180 „
5,000 „ „	200 „

List of Woods that can be Exposed in Water.

Elm, alder, white cedar, plane, acacia.

The jarrah and other Australian specimens of eucalypti all resist the attacks of sea worms and white ants if cut before the sap commences to rise.

Note on Speaking Tubes and the Velocity of Sound.

The velocity of sound through air is at—

32° F.	1,093	feet per	second.
40° F.	1,102	„	„
50° F.	1,113	„	„
60° F.	1,124	„	„
70° F.	1,135	„	„
80° F.	1,146	„	„
90° F.	1,156	„	„

Through other substances the velocity is :—

Lead	4,030	feet per	second.
Water	4,714	„	„
Pine	10,900	„	„
Copper	11,666	„	„
Oak	12,622	„	„
Fir	15,218	„	„
Iron	16,822	„	„

The intensity of sound is inversely as the square of the distance.

A speaking tube 1 inch diameter, made of zinc with several bends ½ mile long, was perfectly distinct; ¾ inch is the minimum, and 1½ inches the maximum diameters for speaking tubes. The velocity of sound through speaking tubes should be but little less than 1,100 feet per second.

Glazing and Painters' Work.

In erecting iron roofs lighted with glass skylights, the system of glazing known as Rendle's patent is most advisable. The squares of glass are fixed without puttying, and the result is economy both in that and in painting. Painting in oil, ordinary colours, per yard superficial, is as follows :—

	Days of a Painter
First, or priming coat, on wood	·016
Second, and each successive coat of paint	·014
Knotting, stopping, &c.	·010

	Days of a Painter
First coat of paint on iron	·024
Second, and each successive coat	·015
Iron bar, each coa per lineal yard	·006
Sash squares, each side, first coat, per dozen squares .	·050
„ „ „ „ second coat, per dozen squares .	·040
Tarring flat wood surfaces, each coat	·028

	Days of a Glazier
Crown glass stopped into new sashes, per foot super. .	·019
„ „ old „ „ .	·060
Sheet glass „ new „ (large squares) .	·015
„ „ old „ „ . .	·040
Cleaning windows both sides	·003

It is most essential to buy lead paints when required in large quantities, and to have a sample analysed. A coat of white varnish over paint inside window sills greatly preserves their clean appearance.

THICKNESSES FOR LEAD AND WEIGHTS OF LEAD SHEET.

Weight in lbs. per ft. super	Thickness in inches	Weight in lbs. per ft. super.	Thickness in inches
1	·017	7	·118
2	·034	8	·135
3	·051	9	·152
4	·068	10	·169
5	·085	11	·186
6	·101	12	·203

The usual weights of lead used are :—

For roofs, flats, and main gutters . . .	7lb. lead.
„ hips, ridges, and small „	6lb. „
, flashings	5lb. „
„ cisterns and sinks, bottoms	7lb. „
„ „ , sides	6lb. „
„ soil pipes	8lb. „

No sheet of lead should be laid of a greater length than 10 feet without a break or roll in it to allow of expansion.

The Rate of Interest Property should Yield.

Freehold Property.

Residential land	3 to $3\frac{1}{4}$	per cent.
Agricultural "	$3\frac{1}{4}$ " $3\frac{1}{2}$	"
Ground rents, six times covered	$3\frac{1}{4}$ " 4	"
Building land, unsecured	4 " $4\frac{1}{2}$	"
Country mansions	$4\frac{1}{2}$ " $4\frac{3}{4}$	"
Detached villas near town	$4\frac{1}{2}$ " $4\frac{3}{4}$	"
Town dwelling-houses, 1st class	$4\frac{3}{4}$ " 5	"
" " 2nd "	5 " $5\frac{1}{2}$	"
" " 3rd "	$5\frac{1}{2}$ " $5\frac{3}{4}$	"
" " 4th "	$5\frac{1}{2}$ " 6	"
Business premises in a large town, 1st class	$4\frac{1}{2}$ " 5	"
" " 2nd "	5 " $5\frac{1}{2}$	"
Labourers' cottages	$5\frac{1}{2}$ " 6	"

Leasehold property, not being so secure, should return from $1\frac{1}{2}$ to 2 per cent. higher interest.

Copyhold property should be valued by deducting the cost of its enfranchisement from it treated as a freehold property. In practice copyhold property is worth about five years' less purchase than if it were freehold.

In railway valuations, (1) the value of the land taken, (2) the 'consequential damages' or the loss to owner due to division or severance of the property, loss of tenant, &c., are separately assessed.

Proportional Cultivation of Great Britain.

	Acres
Corn crops	9,300,000
Green "	3,500,000
Grass land	15,800,000
Woods and forest	2,600,000
Uncultivated	25,800,000
Total area of Great Britain	57,000,000

Wells, Sewers, and Shafts.

Tables for Excavation and Liming.

The maximum distance to which earth can be wheeled in barrows economically . = 100 yards.
Ditto, in dobbin carts . . . . . . = 300 „
Ditto, in ordinary one-horse carts . . = ½ mile.

When the distance is over half a mile it will be more economical to use waggons on rails.

A horse barrow-road cannot be economically worked for a less depth than 20 feet.

The Number of Bricks and Quantity of Brickwork in Wells and Cylindrical Sewers for each Foot in Depth or Length.

	Half-brick Thick			One Brick Thick		
	Number of Bricks		Cubic feet of Brickwork	Number of Bricks		Cubic feet of Brickwork
	Laid Dry	Laid in Mortar		Laid Dry	Laid in Mortar	
1·0	28	23	1·6198	70	58	4·1233
1·3	33	27	1·8145	80	66	4·7124
1·6	38	31	2·2089	90	74	5·3015
1·9	43	35	2·5035	102	82	5·8905
2·0	48	41	2·7979	112	92	6·4795
2·3	53	44	3·0926	122	100	7·0686
2·6	58	48	3·3870	132	108	7·6577
3·0	68	57	3·9760	154	126	8·8357
3·6	79	65	4·5651	174	142	10·0139
4·0	89	73	5·1541	194	159	11·1919
4·6	100	82	5·7432	214	176	12·3701
5·0	110	90	6·3322	234	192	13·5481
5·6	120	98	6·9213	254	209	14·7263
6·0	130	107	7·5103	276	226	15·9043
6·6	140	115	8·0994	296	242	17·0825
7·0	150	123	8·6884	316	260	18·2605
7·6	160	131	9·2775	336	276	19·4387
8·0	170	140	9·8665	358	292	20·6167
8·6	180	148	10·4556	378	308	21·7949
9·0	191	156	11·0446	398	326	22·9729
10·0	212	174	12·2227	438	360	25·3291

The Quantity of Excavation in Wells and Circular Shafts for each Foot in Depth.

Diam.	Quantity	Diam.	Quantity	Diam.	Quantity
Ft.	Cub. yards	Ft.	Cub. yards	Ft.	Cub. yards
3	·2618	5½	·8799	8	1·8617
3¼	·3072	5¾	·9617	8¼	1·9799
3½	·3563	6	1·0472	8½	2·1017
3¾	·4091	6¼	1·1363	8¾	2·2271
4	·4654	6½	1·2290	9	2·3562
4¼	·5254	6¾	1·3254	9½	2·6253
4½	·5890	7	1·4254	10	2·9089
4¾	·6563	7¼	1·5290	10½	3·2070
5	·7272	7½	1·6362	11	3·5198
5¼	·8018	7¾	1·7472	12	4·1888

Contents of Carts and Barrows for Contractor's Work in moving Earth, etc.

A wheelbarrow, light	holds	$\frac{1}{18}$	yards cube.
„ ordinary	„	$\frac{1}{14}$	„
„ large (navvy)	„	$\frac{1}{10}$	„
A dobbin cart	„	$\frac{3}{4}$	„
A one-horse cart (6ft. × 3½ ft. × 2⅓ ft.) . .	„	1⅔	„
An earth waggon, small, filled to level of sides, as with gravel, sand, &c.	„	2	„
Ditto, ditto, when heaped as with earth or clay	„	2½	„
Ditto, large, filled to level of sides . . .	„	2¼	„
Ditto, ditto, heaped	„	3	„

Traction.—The resistance offered by wheelbarrows, carts, or waggons, when drawn along a horizontal road with a velocity not exceeding four miles per hour, is proportional to the load directly, and inversely to the diameter of the wheels.

A barrow, with wheel 18 in. diam., on hard dry earth, requires to move it . . .	$\frac{1}{14}$	part of the weight.
Ditto, ditto, on a wooden plank . . .	$\frac{1}{25}$	„
A cart, with wheels 4 feet diam., on hard dry earth	$\frac{1}{40}$	„

A waggon, with wheels 2 ft. 9 in. diam., on ordinary contractor's rails (straight) in wet weather	$\frac{1}{80}$ part of the weight.
Ditto, ditto, in dry weather	$\frac{1}{120}$,,
Ditto, ditto, on a well-made railroad . .	$\frac{1}{280}$,,

The traction on an inclined road = that on a horizontal one *plus* the weight of the load and that of the vehicle multiplied by the rise and divided by the length of the road.

Comparative Strength of a Horse on Inclined Roads.

Strength on a level road			= 1·00
,,	incline of	1 in 100	= ·96
,,	,,	1 in 80	= ·95
,,	,,	1 in 60	= ·94
,,	,,	1 in 50	= ·93
,,	,,	1 in 40	= ·91
,,	,,	1 in 30	= ·88
,,	,,	1 in 20	= ·81
,,	,,	1 in 15	= ·73
,,	,,	1 in 10	= ·56
,,	,,	1 in 9	= ·40
,,	,,	1 in 8	= ·20

Stone.—The Quantity equal to a Ton in Weight.

	Cubic feet		Sup. feet
Vein marble	13	2 in. York paving .	86
Statuary marble . .	13½	2½ ,, ,, .	70
Granite	13½	3 ,, ,, .	57½
Kentish rag . . .	13½	4 ,, York landing .	43
Purbeck	13¾	6 ,, ,, .	28½
Yorkshire	14½	8 ,, ,, .	21½
Blue Lias limestone .	14½	2 ,, Purbeck paving	83
Portland (best bed) .	15	2½ ,, ,, .	66¼
,, (top bed) . .	16½	3 ,, ,, .	55¼
,, (roach) . .	17½	3 ,, Granite . .	54
Cragleith'	15½	4 ,, ,, . .	39
Bath	18	6 ,, ,, . .	27
Caen	18	9 ,, ,, . .	18

The Weights of Limes and Cement.

Measured in Large Quantities.

Description	Weight per Bushel	Weight per Cubic foot
In Lump (from Kiln)—	Lbs.	Lbs.
Plymouth stone lime	70	54·5
Grey Chalk "	56	44·0
Keynsham blue Lias	80	62·4
Lyme Regis "	75	58·5
Ground (Fresh)—		
Plaster of Paris	74	57·7
Keynsham blue Lias	68	49·0
Lyme Regis "	70	54·5
Roman cement	80	62·4
Portland "	110	85·7

Rates for Boiler Insurance.

The Manchester Steam Users' Association rate for boilers within forty miles of Manchester is 1*l.* 11*s.* 6*d.* per boiler insured for 500*l.* The guarantee covers the injury to the boiler or surrounding works in the event of accident.—(Offices, 9 Mount Street, Manchester.)

One *entire examination* of the boiler is required annually when not in steam.

The *periodical examinations* are made about every four months when steam is up.

Employers' Liability Act, 1880.

Insurance Rates for Workmen.

The Employers' Liability Assurance Corporation, 84 King William Street, London, E.C., issue two sets of policies—*one to protect the employer from liability under the Act* should the accident fall within the provisions of the Act, the other a *general policy that covers all accidents and employer's liability,* and which allows sums for temporary disablement through accident on the weekly payment system.

RATES (*Employer's Liability only*).

	Per cent. s. d.	
Brickyards (no steam) . .	2 0	on annual wages paid
„ (steam) . . .	3 0	„ „
Building (scaffolds) . . .	4 6	„ „
Corn mills	3 0	„ „
Engineering works . . .	2 6	„ „
Quarry	4 0	„ „
Timber	3 6	„ „
Horse dealers	6 0	„ „

Joint policies, covering all employer's risks under the Act of 1880, and where the employer is not liable under it, giving compensation to workmen, are issued at the following rates :—

In case of death, one year's wages.

In case of total disablement, one-third of a weekly wage for a period not exceeding twenty-six weeks.

Chapter 42.

An Act to extend and regulate the liability of Employers to make Compensation for Personal Injuries suffered by Workmen in their Service. [*September* 7, 1880.]

'Be it enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows :—

'1. Where after the commencement of this Act personal injury is caused to a workman—

'(1) By reason of any defect in the condition of the ways, works, machinery, or plant connected with or used in the business of the employer; or

'(2) By reason of the negligence of any person in the service of the employer who has any superintendence entrusted to him whilst in the exercise of such superintendence; or

'(3) By reason of the negligence of any person in the service of the employer to whose orders or directions the workman at the time of the injury was bound to conform, and did conform, where such injury resulted from his having so conformed; or

'(4) By reason of the act or omission of any person in the service of the employer done or made in obedience to the rules or byelaws of the employer, or in obedience to particular instructions given by any person delegated with the authority of the employer in that behalf; or

'(5) By reason of the negligence of any person in the service of the employer who has the charge or control of any signal, points, locomotive engine, or train upon a railway . . . .
the workman, or in case the injury results in death, the legal personal representatives of the workman, and any persons entitled in case of death, shall have the same right of compensation and remedies against the employer as if the workman had not been a workman of nor in the service of the employer, nor engaged in his work.

'**2.** A workman shall not be entitled under this Act to any right of compensation or remedy against the employer in any of the following cases; that is to say,

'(1) Under sub-section one of section one, unless the defect therein mentioned arose from, or had not been discovered or remedied owing to, the negligence of the employer, or of some person in the service of the employer, and entrusted by him with the duty of seeing that the ways, works, machinery, or plant were in proper condition.

'(2) Under sub-section four of section one, unless the injury resulted from some impropriety or defect in the rules, byelaws, or instructions therein mentioned; provided that where a *rule* or byelaw has been approved or has been accepted as a proper rule or byelaw by one of Her Majesty's Principal Secretaries of State, or by the Board of Trade or

any other department of the Government, under or by virtue of any Act of Parliament, it shall not be deemed for the purposes of this Act to be an improper or defective rule or byelaw.

'(3) In any case where the workman knew of the defect or negligence which caused his injury, and failed within a reasonable time to give, or cause to be given, information thereof to the employer or some person superior to himself in the service of the employer, unless he was aware that the employer or such superior already knew of the said defect or negligence.

'3. The amount of compensation recoverable under this Act shall not exceed such sum as may be found to be equivalent to the estimated earnings, during the three years preceding the injury, of a person in the same grade employed during those years in the like employment and in the district in which the workman is employed at the time of the injury.

'4. An action for the recovery under this Act of compensation for an injury shall not be maintainable unless notice that injury has been sustained is given within six weeks, and the action is commenced within six months from the occurrence of the accident causing the injury, or, in case of death, within twelve months from the time of death: Provided always, that in case of death the want of such notice shall be no bar to the maintenance of such action if the judge shall be of opinion that there was reasonable excuse for such want of notice.

'5. There shall be deducted from any compensation awarded to any workman, or representatives of a workman, or persons claiming by, under, or through a workman in respect of the cause of action arising under this Act, any penalty or part of a penalty which may have been paid in pursuance of any other Act of Parliament to such workman, representatives, or persons in respect of the same cause of

action; and where an action has been brought under this Act by any workman, or the representatives of any workman, or any persons claiming by, under, or through such workman, for compensation in respect of any cause of action arising under this Act, and payment has not previously been made of any penalty or part of a penalty under any other Act of Parliament in respect of the same cause of action, such workman, representatives, or person shall not be entitled thereafter to receive any penalty or part of a penalty under any other Act of Parliament in respect of the same cause of action.

'**6.**—(1) Every action for recovery of compensation under this Act shall be brought in a county court, but may, upon the application of either plaintiff or defendant, be removed into a superior court in like manner and upon the same conditions as an action commenced in a county court may by law be removed.

'(2) Upon the trial of any such action in a county court before the judge without a jury one or more assessors may be appointed for the purpose of ascertaining the amount of compensation.

'(3) For the purpose of regulating the conditions and mode of appointment and remuneration of such assessors, and all matters of procedure relating to their duties, and also for the purpose of consolidating any actions under this Act in a county court, and otherwise preventing multiplicity of such actions, rules and regulations may be made, varied, and repealed from time to time in the same manner as rules and regulations for regulating the practice and procedure in other actions in county courts.

'"County court" shall, with respect to Scotland, mean the "Sheriff's Court," and shall, with respect to Ireland, mean the "Civil Bill Court."

'In Scotland any action under this Act may be removed to the Court of Session at the instance of either party, in

the manner provided by, and subject to the conditions prescribed by, section nine of the Sheriff Courts (Scotland) Act, 1877.

'In Scotland the sheriff may conjoin actions arising out of the same occurrence or cause of action, though at the instance of different parties and in respect of different injuries.

'7. Notice in respect of an injury under this Act shall give the name and address of the person injured, and shall state in ordinary language the cause of the injury and the date at which it was sustained, and shall be served on the employer, or, if there is more than one employer, upon one of such employers.

'The notice may be served by delivering the same to or at the residence or place of business of the persom on whom it is to be served.

'The notice may also be served by post by a registered letter addressed to the person on whom it is to be served at his last known place of residence or place of business; and, if served by post, shall be deemed to have been served at the time when a letter containing the same would be delivered in the ordinary course of post; and, in proving the service of such notice, it shall be sufficient to prove that the notice was properly addressed and registered.

'Where the employer is a body of persons corporate or unincorporate, the notice shall be served by delivering the same at or by sending it by post in a registered letter addressed to the office, or, if there be more than one office, any one of the offices of such body.

'A notice under this section shall not be deemed invalid by reason of any defect or inaccuracy therein, unless the judge who tries the action arising from the injury mentioned in the notice shall be of opinion that the defendant in the action is prejudiced in his defence by such defect or inaccuracy, and that the defect or inaccuracy was for the purpose of misleading.

'8. For the purposes of this Act, unless the context otherwise requires,—

'The expression "person who has superintendence entrusted to him" means a person whose sole or principal duty is that of superintendence, and who is not ordinarily engaged in manual labour:

'The expression "employer" includes a body of persons corporate or unincorporate:

'The expression "workman" means a railway servant and any person to whom the Employers and Workmen Act, 1875, applies.

'9. This Act shall not come into operation until the first day of January one thousand eight hundred and eighty-one, which date is in this Act referred to as the commencement of this Act.

'10. This Act may be cited as the Employers' Liability Act, 1880, and shall continue in force till the thirty-first day of December one thousand eight hundred and eighty-seven, and to the end of the then next Session of Parliament, and no longer, unless Parliament shall otherwise determine, and all actions commenced under this Act before that period shall be continued as if the said Act had not expired.'

The Agricultural Holdings Act (England), 1883.

Drainage.

Capital money under the Settled Land Act 1882 may, under Section 25 of that Act, on a certificate of the Land Commissioner, or of a competent engineer, or an order of the Court, be applied in Drainage Works.

A tenant for life of a settled estate is thus enabled to sell a portion of his land for the purpose of executing drainage works on the remaining portion. (See also 8 & 9 Vic. c. 56.)

See also Public Money Drainage Acts—viz. 9 & 10

Vic c. 101, 10 & 11 Vic. c. 11, 11 & 12 Vic. c. 119, 13 & 14 Vic. c. 31, 19 & 20 Vic. c. 9.

See also Improvement of Land Act, 1864—viz. 27 & 28 Vic. c. 114.

Improvements to which consent of Landlord is required under 1883 *Act.*

Erection or improvement of buildings.

Formation of silos.

Laying down permanent pasture.

Making and planting osier beds.

Water meadows and irrigation works (new).

Water gardens (new).

Making or improving roads or bridges.

Making or improving ponds, watercourses, wells, reservoirs, water power, water supply.

Making fences.

Planting hops.

Planting orchards or fruit bushes.

Reclaiming waste land.

Embankments and sluices against floods.

Notice of *intended drainage by tenant* must be given to Landlord.

Consent of Landlord is NOT *required to*—

Boning land with undissolved bones.

Chalking land.

Clay burning land.

Claying land.

Liming land.

Manuring land.

Application of artificial manures or consumption of corn or cake, &c.

Silos and Ensiling.

Great hopes have been expressed that hay might be turned to profitable account by the above in long-continued spells of wet weather. The process of ensiling green crops is not by any means a new one, but lately it has been the subject of much discussion, so that some reference should be made as to the cost of the process and the success that those who have tried it have met with.

There are at present in this country a total of 610 silos, of which 36 are situated in Wales, 60 in Scotland and 514 in England.

The temperature ranges in the silos from 90° F. to as high as 120° F., but should go over 125° F. at a pressure of 200 lbs. per sq. foot. The methods of securing the pressure are by weights made variously of pig iron, cement, boulders laid on the covering planks by hand labour and so removed, hydraulic jacks, and special mechanical processes, none of them very perfect. The admission of air trebles the amount of decomposition, and large quantities of carbonic acid are given off. The cost of the construction of silos in brick and cement averages from 14*s*. 6*d*. per ton of ensilage made to 1*l*. 1*s*. 10*d*. per ton.

It is important that a bed of concrete not less than 12 inches in thickness should form the floor of the silo, so that in converting old barns into silos especial care should be taken on this point, and the foundations of the walls examined, otherwise when pressure comes to be applied the walls may give outwards.

Pressure should be applied mechanically; it enables the owner to fill up the silo without having to expend labour every time in putting the hand weights on and off; further, to have some 20 tons of pig iron at 40*s*. lying on every farm merely as weights is not an economy.

Reynolds's process of applying pressure by means of

chains, beams, and tighteners is worthy of attention. For instance, a silo 15×12 feet wide is to have a pressure of 200 lbs. per square foot.

Two beams, with 2 chains on each beam, will be required when 8 tons pressure is exerted on each beam, in all 16 tons; this divided by the area of the silo, 15×12 feet $= 200$ lbs. per square foot pressure on the silage.

SPECIFICATION OF REYNOLDS'S SILO.

	£	s.	d.
A silo 60 × 12 feet deep × 12 feet wide. Pressure to be 200 lbs. per sq. foot, requires 8 beams, 9 inches wide × 7 deep, carrying 16 chains each of 20 feet, in all 320 feet of chain, at 1*s*. per foot	£16	0	0
16 sets cast-iron brackets for chain rollers provided with coach screws for screwing to ends of beam, at 8*s*. per set	6	8	0
Sixteen washer plates with pins, each 2*s*. . .	1	12	0
One 4-ton screw chain and stretcher, with hooks	4	0	0
Two cast-iron chain rollers, each 10*s*. . .	1	0	0
	£29	0	0

That a farmer should have the power and means of ensiling his hay, &c., is obvious enough in a climate with a rainfall like England has; to depend upon it is to strain the object. To tell him that it will do marvels for him is to mislead him. At the present stage of the question the desirability of converting useless buildings, when possible, into silos is decided in the affirmative; that of whether a landlord shall erect new silos at his own expense for the use of the tenant, I think is one that the evidence of necessity before the agricultural community does not justify to be answered in the affirmative at present. But the question is one solely devolving upon the modern practice of agriculture; the rules for construction are the same as for any other similar structure, it being noted that on gravel and such strata are the most preferable sites for pit silos, as the ballast

excavated will serve to make the concrete necessary for the work, and that the admission of air regulates the waste of material due to partial or incomplete combustion. The class of fermentation to be aimed at is that of the fermentation in a well-filled sealed flask in a laboratory rather than the destructive type, such as spontaneous combustion due to excessive temperature produced by rapid oxidation.

The usual chemical changes which are the result of ensilage appear to be fairly represented by the following analysis, from which it will be seen that there is an increase in flesh-forming compounds and a decrease in indigestible fibre:—

CLOVER-HAY AND SILAGE (dried to 212° F.).

	Hay	Silage
Albuminoid substances, soluble . . .	2·87	7·55
„ „ insoluble in water .	7·83	4·89
Sugar, gum, and extractive matter . .	47·31	53·44
Fatty matter, chlorophyle, &c. . . .	2·96	3·11
Indigestible wood fibre	32·84	22·16
Mineral soluble in water	2·51	5·71
„ insoluble „	3·68	3·14
	100·00	100·00

Farmers intending to emigrate should study the construction of silos at home, before leaving. The first year of settling after clearance to be able to ensilage the green crops may be of great assistance to the emigrant who is short of labour, and whose attention can be thereby turned to other matters, and so secure that 'good start right away' that makes him in the future. It is the number of things to be done, and himself being the only man there to do them, that is the difficulty to the newly arrived settler; and here let me advise all who think of emigrating, to first learn at home the rudiments of surveying, the use of carpenter's tools, blacksmith's work, and how to lay bricks. To come out

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ignorant of such things is to have to pay dearly for such work, and if a bad season or two to start with takes the emigrant's capital, to be adrift in a colony without a handicraft to fall back on, pending a fresh start, is to go through an amount of misery that most avoid by degenerating into a 'sundowner' or tramp, who goes from station to station existing on what may be given him, and often starving. But if a man comes out to a colony with a knowledge of such trades as I name, he can soon earn enough to start by exercising his handiwork on stations, and so gaining his experience gratis *before* risking his capital. The colonies are made up of two classes, capital and no experience, and experience and no capital, and it is solely the result of what I have frequently said here, and what emigrants *bitterly* realise the truth of when they meet with their first reverse, have gained the experience and lost their capital, that to emigrate to farm without knowing a useful trade is to run a very good chance of starvation.

Reverting to the original subject of ensilage, the writer anticipates that no difficulty will be found in construction if a proper foundation be secured. The uses and advantages of the process are purely an agricultural and commercial question for discussion. It would seem that a temperature of 125° F. is fatal to the bacteria of acid fermentation, and with regular pressure, sweet ensilage is secured.

Notes on Abyssinian Tube Wells for supplying Stock. Legrand and Sutcliff's Patents.

Reference was made to tube wells in the chapter on Water Supply, but some further details are given here as to cost and method of putting down the tubes. Of the advantages of the systems there can be no question, yet they are not used for the simple reason that, like many other modern and valuable engineering appliances, land agents and tenant

farmers do not know of their existence until someone tries the experiment. The slightest reflection will convince the owner of land that, if he can screw down a pump anywhere and get water, to sink a well is a useless expense. The writer knows a case where a farm was thus provided with a water supply of 300 gallons per hour during the drought (1884), and let for the *only* reason that it had a water-supply at hand, after having been advertised in vain. The enormous waste of time and labour on some farms in fetching water appears incredible to an engineer, yet it is but an instance of the want of the knowledge of modern means and appliances.

Driving the Tubes.—The first tube is of specially tough iron, pointed with holes perforated into it of $\frac{1}{8}$ to $\frac{1}{4}$ inch diameter. The point is made like a bulb, to allow for the downward passage of the socket joint of each successive length of tube. To the head of this first tube a clamp provided with steel teeth is fastened. This is tightly screwed up to the tube by means of two bolts. Next a monkey weight is slipped on to the tube, or cast-iron driving weight, which is raised and let fall alternately by means of pulleys and ropes, as in the practice of driving piles. Every time the monkey falls on the clamp, if the clamp is kept well screwed up to grip the tube tightly, so that no slipping takes place, the tube penetrates the ground. When the clamp is driven down by the tube sinking out to the surface of the ground, a fresh length of tube is screwed on, the clamp released, lifted higher up number 2 tube, tightened, and driving recommences again. Tube after tube is thus driven down till water is reached. The blow of the monkey and direction of the tube are to be carefully kept truly vertical in driving, being frequently plumbed for accuracy. Two men are required for the work. Another arrangement admits of the blow being given down the tube itself at the very point where the perforation of the earth has to take

place. This is effected by a steel plug which is afterwards removed. The rate of progress is as much as 70 feet a day in loose gravel and clay.

The clearance of the perforated holes and tubes of earth, when the driving down is finished, is the next step. The presence of water is first denoted by trying with the plumb bob. A special form of syringe pump is used, which alternately syringes water down inside the tube and out through the perforations and sucks it up again. The great secret lies in continuing this syringing till a cavity is formed all round the point of the first tube—in fact, a sort of well and filter bed.

The whole being so far satisfactorily established, the process of pumping may be thus described.

Pumping from Tube Wells.—The joints in each tube having been made thoroughly tight with white lead, the pump supplied acts in the following way:—All atmospheric pressure is removed from the water in the tubes at each stroke of the pump; pressure being transmitted equally and in all directions by fluids, it follows that the water flows to the tube by being drawn there, and not by mere gravitation. The pressure that is on the water pumped may be exerted on it a mile or so away underground. Hence the large supply.

In coupled tube pumps, tubes are sunk over a considerable area, and are connected together by a horizontal main, which is pumped out by a steam engine; thus the friction of drawing so large a body of water to one spot by one channel is avoided, and, what is important to observe, the underground water communications are extended and maintained over a large area, and the water level is thus not so quickly lowered by long-continued pumping. Thus at West Thurrock, in Essex, two 5-inch tube wells coupled together, each about 80 feet deep, yield a joint total supply of 220,000 gallons per day; at Northfleet another similar system yields

60,000 gallons per day; in neither case did the cost exceed 60*l.* each. Thus it will be seen that, the water level underground being once clearly established by a percussion tube well being driven on an estate, the supply of water in a way that is proof against contamination for stock can be obtained at a definite cost and with but little labour. It may become advisable to license dairy farms and to regulate their internal arrangements to secure purity and sanitary precautions; without which epidemic disease is always liable to occur. To attempt to make a cheese factory or dairy farm succeed without securing an ample supply of pure water is waste of time and money, and this rule may well be taken to heart. Before anything is done towards establishing a milk factory, or any such system, first bore for water, and gauge the quantity and quality of the water. Use tube wells only and contamination is impossible; but this is not done, and the writer knows of more than one lamentable failure through neglect of the agent to deal with the water supply first.

TABLE OF COST OF TUBE WELLS FOR SINKING BY PERCUSSION.

Diameter of tube	Yield per minute	Cost (fitted up complete) £ s. d.		£ s. d.
1¼ inches	6 to 12 gallons	6 10 0	to	10 10 0
2 "	6 to 14 "	10 10 0	"	18 0 0

At Much Hadham two 1¼-inch tubes were driven 44 feet each, and at a total cost of under 36*l.*, yielded a supply of 400 gallons per hour, fixed with pumps complete.

AVERAGE COST OF MATERIALS.

Tube well without pump	1¼ inch tube, inside diameter £ s. d.	2 inch tube, inside diameter £ s. d.	3 inch tube, inside diameter £ s. d.
12 feet	2 10 0	5 0 0	10 0 0
18 "	3 10 0	7 0 0	14 0 0
24 "	4 10 0	9 0 0	18 0 0
30 "	5 10 0	11 0 0	22 0 0
36 "	6 10 0	13 0 0	26 0 0
Extra (per foot).	0 3 4	0 6 8	0 13 4

The pump for the head of the tube costs from 3*l.* to 4*l.* In all cases an experienced well-driver should be hired from the makers (100 Bunhill Row, London, E.C.), which may be done for 10*s.* per day, and two labourers will have to be found by the agent from the estate. Before driving with a 3-inch tube it is necessary to test with a 1¼-inch tube first. This class of tube well is for clay, gravel, and sandy soils only.

TABLE OF COST OF ARTESIAN BORED WELLS. COST OF BORING ONLY (EXCLUSIVE OF TUBES, &C.) FROM SURFACE. FOR LARGE SUPPLIES OF WATER FROM DEEP STRATA.

In easy strata such as alluvial soil :—

	Feet		*s.*		*s.*	
Not exceeding . .	100	from	10	to	20	per foot.
„ . .	200	„	15	„	30	„
„ . .	300	„	20	„	40	„
„ . .	400	„	25	„	50	„
„ . .	500	„	30	„	60	„

According to size of hole and strata.

COST OF BORING IN BLOWING SANDS, ROCK, STONE, &C.

		s.		*s.*	
100 feet	from	20	to	60	per foot
200 „	„	30	„	80	„
400 „	„	35	„	90	„
500 „	„	40	„	100	„

These prices are for borings 3 to 7 inches diameter; the tubes costing from 4*s.* to 14*s.* per foot ready with steel sockets screwed.

These prices are only given to form some idea of the cost of supply by artesian bored tube wells, and the percussion tube well or Abyssinian pump. Such work is best undertaken by contract with the makers, unless some one on the estate has had previous experience of the work. At Burton-on-Trent about 2,000,000 gallons of water are got daily from these tube wells, which are coupled for supply in series. The great advantage lies in tube wells being proof

from surface contaminations; thus they are best for cottages and in villages for supply.

Note on Impurities in Creasote for Preserving Woodwork and Hop-poles, Railway Sleepers, &c.

Of late years the adulteration of creasote has increased to such an extent that engineers have found it desirable to draw up a specification of quality when ordering it. It is advisable that the Royal Agricultural Society's directions for analysis and security of samples be strictly adhered to, and a sample sent to their chemist for analysis drawn from that supplied *before any is used* or any acceptance of delivery made.

Specification for Creasote.

1. The liquor must be free from the admixture of any oil or other substance not obtainable from the distillation of coal at temperatures ranging between 350° F. and 760° F.

2. It must yield 65 to 70 per cent. of products when distilled from its boiling-point to 610° F.

3. By repeated agitation with successive portions of solution of caustic soda of 1·125 (25° Twaddell) specific gravity, the distillate must yield not less than 10 per cent. of crude carbolic and cresylic acids (coal-tar acids).

4. The creasoting liquor shall contain not less than 20 and not more than 30 per cent. of constituents that do not distil over at a temperature of 610° F.

5. It should become completely fluid when raised to a temperature of about 95° F., and remain so whilst cooling to a temperature of 85° F.

6. Water being 1,000 at 60° F., the specific gravity of the liquor must not be less than 1,035, nor more than 1,065 in proportional specific gravity.

If an analysis of the sample taken from bulk is in accordance with these tests the creasote may be used; if not,

it should be returned 'not according to specification.' Except creasote contains at least 9 per cent. of crude carbolic acid it is, in my opinion, valueless to use on wood as a preservative, and experience on railways and in coal mines with sleepers and supports confirms the amount necessary at 10 per cent. With that quantity it is decidedly the most effective preservative of timber we have, capable of easy and direct application.

Where it is stored, there should always be kept a few buckets of sand in case of fire—water is of no use. It should never be stored in farm buildings.

Measurements of Land.

Dimensions of a statute acre in yards, from 1 *to* 100 *yards by length.*

Length	Width			Length	Width			Length	Width		
Yds.	Yds.	ft.	in.	Yds.	Yds.	ft.	in.	Yds.	Yds.	ft.	in.
1	4840	0	0	26	186	0	6	51	94	2	9
2	2420	0	0	27	179	0	10	52	93	0	3
3	1613	1	0	28	172	2	7	53	91	1	0
4	1210	0	0	29	166	2	9	54	89	1	11
5	968	0	0	30	161	1	0	55	88	0	0
6	806	2	0	31	156	0	5	56	86	1	4
7	691	1	4	32	151	0	9	57	84	2	9
8	605	0	0	33	146	2	0	58	83	1	5
9	537	2	4	34	142	1	1	59	82	0	2
10	484	0	0	35	138	0	11	60	80	2	0
11	440	0	0	36	134	1	4	61	79	1	1
12	403	1	0	37	130	2	6	62	71	0	2
13	372	1	0	38	127	1	2	63	76	2	6
14	345	2	2	39	124	0	4	64	75	1	11
15	322	2	0	40	121	0	0	65	74	1	5
16	302	1	6	41	118	0	2	66	73	1	0
17	284	2	2	42	115	0	9	67	72	0	9
18	268	2	8	43	112	1	9	68	71	0	7
19	254	2	3	44	110	0	0	69	70	0	6
20	242	0	0	45	107	1	8	70	69	0	5
21	230	1	6	46	105	0	8	71	68	0	7
22	220	0	0	47	103	0	0	72	67	0	8
23	210	1	4	48	100	2	6	73	66	0	11
24	201	2	0	49	98	2	4	74	65	1	3
25	193	1	10	50	96	2	5	75	64	1	8

Measurements of Land—*cont.*

Length	Width			Length	Width			Length	Width		
Yds.	Yds.	ft.	in.	Yds.	Yds.	ft.	in.	Yds.	Yds.	ft.	in.
76	63	2	1	85	56	2	10	93	52	0	2
77	62	2	7	86	56	0	11	94	51	1	6
78	62	0	2	87	55	1	11	95	50	2	11
79	61	0	10	88	55	0	0	96	50	1	3
80	60	1	6	89	54	1	2	97	49	2	9
81	59	2	4	90	53	2	4	98	49	1	2
82	59	0	1	91	53	0	7	99	48	2	8
83	58	1	0	92	52	1	10	100	48	1	3
84	57	1	11								

A Ready Reckoner for the Land Surveyor.

The following table gives the value of land per yard and per acre of* 4,840 *square yards.

Per sq. yd.			Statute acre.		
£	*s.*	*d.*	£	*s.*	*d.*
0	0	3	60	10	0
0	0	6	121	0	0
0	1	0	242	0	0
0	2	0	484	0	0
0	2	6	605	0	0
0	3	0	726	0	0
0	3	6	843	0	0
0	4	0	968	0	0
0	4	6	1,089	0	0
0	5	0	1,210	0	0
0	5	6	1,331	0	0
0	6	0	1,452	0	0
0	7	6	1,815	0	0
0	10	0	2,420	0	0

Per sq. yd.			Statute acre.		
£	*s.*	*d.*	£	*s.*	*d.*
0	12	6	3,025	0	0
0	15	0	3,630	0	0
0	17	6	4,235	0	0
1	0	0	4,840	0	0
1	5	0	6,050	0	0
1	10	0	7,260	0	0
1	15	0	8,470	0	0
2	0	0	9,680	0	0
2	10	0	12,100	0	0
3	0	0	14,520	0	0
3	10	0	16,940	0	0
4	0	0	19,360	0	0
5	0	0	24,200	0	0

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